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6 REAL TIME OPERATIONAL CONTROL OF MIRANDA

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SUMMARY

This Report describes the automatic control techniques developed and used for the operational control of Miranda (X4), the first British 3-axis stabilised satellite. The operational control techniques are a development of those used for Prospero and the more important improvements are described. Explanation of, and experience in the use of these techniques during the lifetime of the satellite are given.

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CONTENTS

1 INTRODUCTION

Miranda[1], previously known as X4, the second satellite in the National Space Technology programme, was launched in a southerly direction by an American Scout Rocket from the Western Test Range, California, at 02h 22min 12s GMT on 9 March 1974. Miranda was the first British 3-axis stabilised satellite; despin, separation and sun lock were successfully achieved and the satellite placed in a sun synchronous orbit of inclination 97.8° with an apogee of 933km and perigee 718km.

Designed to demonstrate accurate 3-axis stabilisation using a gyro controlled inertial platform and a propane gas system to provide control torques, Miranda used sun sensors to update the yaw and roll gyro references to maintain accurate sun pointing. Changes in attitude could be made by the application of different rates of rotation of the satellite about the pitch axis. Additional experiments included an infra-red sensor, a star sensor, a new type of albedo sensor and patches of experimental lightweight solar cells, which did not contribute to the satellite main power supply. A new design high power lightweight solar array provided electrical power. The satellite is illustrated in Fig.1 and is fully described in Appendix A.

On the first revolution the NASA Telemetry and Telecommand station at Tananarive (Madagascar) was used to implement a special contingency procedure (described in Appendix B). Data were received at the Telemetry and Telecommand station at Lasham on the first pass at 03h 37min 00s GMT and control of the satellite throughout was exercised from the satellite control centre at RAE, Farnborough (described in Appendix C and hereafter referred to as CC).

Miranda was designed to work for a nominal lifetime of six months in an all sunlit orbit, but continued to function for nine months, the last of which was spent in eclipsing orbits.

The satellite worked well in orbit apart from a period early in life when the gas jet control system did not function correctly and two occasions during which there were major electronic problems. The gas system problem persisted for a few months, gradually becoming less troublesome and the experimental programme was able to proceed, albeit to a modified plan. All of the major and most of the minor experimental objectives were achieved.

This Report describes the operations philosophies and discusses the automatic control techniques for performance assessment and implementation of

the in-orbit experimental programme. It also briefly describes the experimental objectives achieved together with comments on the orbital life of Miranda.

The main text of this Report has been written for the general reader but the appendices contain more detailed information.

2 OPERATIONS DISCUSSION

The real time operations performed by the CC and ground station are very similar for any satellite in near earth orbit. Operations can be summarised as follows:

(a) Acquisition of telemetry signals from the satellite.

(b) Testing for correct functioning of the satellite by examination of certain critical subsystem and experiment parameters.

(c) The sending of commands to correct anomalies in satellite behaviour, should this be necessary.

(d) The dumping of stored data if the satellite has an on board data store. In this way, data are obtained for those periods when the satellite is out of range of a ground station, and with suitably situated ground stations (their locations depending on the orbit inclination), whole or nearly whole earth coverage can be achieved.

(e) Implementation of the in orbit experimental programme. This will vary considerably depending on the type of satellite. The requirement could be simply to receive and record data at the ground station, alternatively to send a command or sequence of commands to change a function of one of the systems of the satellite - an attitude manoeuvre, for example.

(f) The monitoring for loss of satellite signal at the end of the pass.

When a great many operational tasks are to be performed in as little as six minutes of communication, use of a computer is essential to achieve the necessary reliability and speed of implementation.

At all times during the pass unprocessed telemetry data and commands are recorded on an instrumentation tape recorder at the ground station. These data contained on this master tape may be used for subsequent processing if required. Normally, an additional recording is made at the CC (for convenience). The master tape is usually kept for one or two years, even though all data have been successfully written to digital tape in real time. Throughout a satellite pass CC and ground station staff must be able very quickly to command the satellite into a safe state if an unexpected or obscure problem arises.

Some aspects of post pass evaluation of the telemetry data are also common to all satellites inasmuch as a summary of the state of a satellite's 'health' is normally required. Obviously, other post pass evaluation is dependent on the nature of the satellite, its subsystems and experiments and the experimental programme. The more important philosophies used for operational control of satellites by RAE are:

(a) Control by exception: a technique analogous to management by exception is used. Messages output to the control staff indicate progress through the automatic sequence of operations, telemetered performance and status parameters outside the limits for correct operation, and ground station problems detected by the status monitoring system. This approach allows the operations staff to monitor the pass, but to remain alert to deal with unexpected problems. This is important since it greatly assists the avoidance of human error in stressful situations.

(b) Preplanning: the operations for a pass vary considerably in detail, with different equipment configurations for various subsystems and experiments, different commands or command sequences to be sent. The precise operational requirements are pre-planned and a pass schedule produced. Information from this are fed into the operations program by the teletype before the pass starts and operations are performed automatically during the pass. In this way, the burden of remembering what to do and when to do it is taken away from the operations staff and carried by the computer.

(c) Automatic control: the primary consideration in the system design was the safeguarding of the satellite at all times and the rapid performance of operational tasks.

It is neither practicable nor necessary to examine all data in real time. The operational tasks to be performed in real time are dealt with in sequence, one of the most important being to establish that the satellite's main subsystems are functioning normally before proceeding with the experimental programme. Certain parameters in the telemetry format can be used to define 'normal functioning' and once it has been established that the satellite's 'health' is good, the next operation can take place. It is unlikely that after a 'health' check has been made a change would occur during a pass unless the state of the satellite were changed by command therefore no parallel assessment of performance in conjunction with other operational activities is required. It would in any case unnecessarily complicate the operations system design. It should be noted that provision must always be made for a rapid assessment or re-assessment of

any subsystem performance during a pass, and a high priority was placed on this in designing the operations system.

Certain remedial actions to safeguard the satellite are performed either completely automatically or on initiation by the teletype operator at the satellite controller's discretion. When a message indicating incorrect satellite operation or status is output on the operations teletype, the actions performed depend on its significance. If the warning print out is of a major nature, e.g. if the symptons are consistent with a predicted failure case, the appropriate remedial action will be automatically taken by program. In this case, the warning message will be followed by another message indicating the command or sequence of commands to be sent. If the warning print-out is of a minor nature it contains a question asking the controller if remedial action is to be taken. (He instructs the operator to type either 'yes' or 'no' on the operations teletype in response.) If the answer is 'yes', then the remedial commands are initiated by the program.

As with the telemetry processing hardware the Lasham command station has been made into a peripheral of the computer and brought under its control. In this way, the data loop from satellite back to satellite is closed by the computer. This is an important innovation since there is no reliance on operators (except in certain situations when commands are initiated from the operations teletype) in sending of routine, planned or emergency commands.

Various other CC equipment which, although not part of the automatic control loop, are essential to the pass operations and are also under computer control. The performance of various tedious yet essential tasks is therefore carried out automatically, allowing the operations team to concentrate on their proper work.

The use of these techniques enables operations to be performed with a minimum of staff.

3 MIRANDA OPERATIONS REQUIREMENTS

The CC and ground station were originally set up for the operational control of Prospero, which has completed four years in orbit. A reliable, efficient and safe method of automatic control had been developed in RAE and used for the in-orbit control of Prospero[2] and the same general philosophies were applied to Miranda. To control the Miranda operations, additional items and modifications to equipment for the CC and ground station were required.

The much more stringent operational requirements of Miranda led to changes to the CC and ground station interface and to software.

3.1 Changes and additions made to equipment

A major part of the telemetry and telecommand station is ex-ELDO equipment originally sited at GOVE in Australia. The original layout of this equipment was not consistent with the planned operations for Miranda. The equipment was dispersed and units associated with one function were not necessarily grouped together. An exercise in ergonomics was carried out to ensure that the prime station functions could be controlled by two people only - one responsible for tracking and receiving equipment and the other, the Shift Leader, for back up command control and telemetry data evaluation. One further important change was made. An equipment status system was provided so that at any time the selection and readiness status of all essential equipment was indicated by a lamp display on a common panel with status selection push buttons. The status information was fed via the return leg of the telecommand link to the control centre in order to present on a lamp display the Go/No-Go status of the different functions of the Lasham station. Status information was also fed into the computer and monitored by the operations program.

The more stringent real time operational requirements and the implementation of the in-orbit operations programme necessitated changes to CC equipment and the need to run many large programs after each pass necessitated an increase in the size of both core store and backing store. Experience from the control of PROSPERO showed that it would be beneficial if certain non-computer equipment were under computer control - the analogue tape recorder, for instance. For this reason, an 8 × 8 matrix relay buffer controlled by the computer was designed and built in RAE.

The physical layout of equipment in the CC was reorganised. Two main criteria were set down as a guide to equipment positioning:-

(a) Noise.

(b) Susceptibility to dust, temperature and humidity.

As a result of this reorganisation, the computer, the digital tape machines, and the disc stores were housed separately from the other CC equipment in air-conditioned and humidity controlled rooms. In this way, a much quieter environment for the operations staff was achieved.

3.2 Ground station and control centre interface

For Prospero operations, the data link between the two stations consisted of a pair of high quality telephone lines with a further pair as back up. However, data quality was rather unreliable (based on periodic bit error measurements) mainly, it was believed, because the cable routings were not direct but were fed through various telephone exchanges. The signal/noise ratio on this link was improved by approximately 5dB by the introduction of asynchronous modems - with a corresponding decrease in bit error rate.

For Prospero, commands were initiated by program or operator and sent from the RAE telecommand station at Farnborough. Since the Lasham station command aerial can be slaved to the telemetry aerial, and the equivalent isotropic radiated power (EIRP) of the station is higher, it was considered more reliable to send commands using the Lasham facility but automatically initiated from the CC program. A special purpose link[3] was designed in Space Department which provided the requisite error detection. Standard synchronous modems and PO lines were used with special purpose terminals. In this manner, the command facility at Lasham became a peripheral of the CC and under direct computer control. Status information generated by the command station as a result of a command instruction (e.g. - command encoder busy; command transmitter carrier radiating) are returned over the same link for use by the operations control program.

As part of the satellite test plan, compatibility trials were performed to test uplink and downlink capabilities with the Lasham ground station and to test the real time control software at the CC. Both engineering and flight models of the satellite were involved in these trials and, as far as possible, automatic remedial sequences were tested. Undoubtedly, the value of such trials have been reflected by the success of the orbital operations of Miranda, particularly during the periods when the satellite malfunctioned.

3.3 Software

Flang[4] is the name of the flow chart language developed in RAE. The real time operational tasks are produced as a series of conventional flow charts. The operational tasks depicted by the flow charts are coded in a manner designed for the language. These coded flow charts are translated by a program called FLT which produced an internal flow chart code on a disc store. The internal code is interpreted at run time and the sequence of operational tasks performed. This interpreter program is called FLINT.

Perhaps the easiest way to visualise the flow chart concept is to imagine the programmer as producing a set of building bricks or subroutines, each specified by the satellite controller who then arranges them into the structure that is required during the pass. Once the specifications have been agreed, software and flow charts can be developed independently. A ready understanding of the various paths through the control programs is best obtained by visualising them as flow charts; it is extremely difficult to obtain the same understanding from program listings, particularly where loops and branches occur. This point is very well illustrated in Appendix B which describes the use of the NASA telemetry station at Tananarive. For the relatively simple task being performed, a flow chart was devised (see Appendix B, Fig.B1) which describes the procedure in a visual form. It is surprising to note the degree of complexity in operations even when the ground station is manually controlled. Other advantages of the flow chart method are:

(a) the software specialist needs to know little about the satellite systems,

(b) the satellite controller need not be familiar with computer programming,

(c) a change in the operations flow charts would not affect the software specialist except where a new feature was required. In this case, the writing of a subroutine (or routines) to provide the new feature would be made without any change to software previously written, and

(d) a change in the method by which a routine performs a function, has no effect on the work already done by the satellite controller, providing the specification for the routine has not been changed.

The system design considerations of this Report deal with the flow charts themselves and not with FLINT and FLT. However, it is important to mention one design change within FLINT. This is the capability to record all the telemetry data together with relevant time information onto an industry compatible computer tape in real time. The digital tape for Prospero had been obtained by replaying the serial (instrumentation) tape after each pass. For Miranda it was essential that an immediate post pass analysis be made for the following reasons:

(i) to provide information for the implementation of some aspects of the operations program,

(ii) to provide data on which the immediate experimental programme was based, and

(iii) to provide 'forecasting' information upon which remedial actions for subsequent passes could be made.

This change speeded up the post pass evaluation and reduced the effort needed.

The complete Miranda orbital operations were devised before launch and presented in the form of flow charts. The operations were designed so that as far as was practicable, no real time operator decisions were required during a pass. The criterion could not of course always be met and sometimes it was necessary for decisions to be made as a result of an emergency situation but they usually required a simple yes/no answer from the satellite controller; the program implementing the action. Routine passes including the sending of multiple and direct commands to the satellite were frequently carried out with no operator intervention from acquisition of signal (AOS) to loss of signal (LOS).

For Miranda, special control techniques had to be designed for real time operational control. Some of these techniques are complicated because of the satellite system design, others because of the nature of the in-orbit experimental programme. To use these techniques, the software had to be expanded to include the additional functions. A large amount of bit manipulation for both telemetry verification and in the forming of command patterns was required. Also, since more items of equipment, both at the CC and the ground station, were under computer control, flow charts had to be developed to enable non-computer peripherals to be controlled.

It would be impracticable to describe here every subroutine in the suite of programs since there were approximately twice as many different types of actions and tests as were used for Prospero. The new functions considered to be of greatest importance will be described below but a complete list and brief definition of each action and test are given in Appendix F.

3.3.1 Registers

Two hundred 16 bit registers were made available in the program and used for the storage of:-

(a) planned command patterns,
(b) expected satellite status,
(c) actual satellite status,
(d) actual satellite analogue parameter values, and
(e) analogue parameter limits (upper and lower).

Registers were also used extensively for bit manipulation. Using the registers and associated action and test boxes, it was possible to carry out:

(i) left or right shifting of register contents,

(ii) comparison of the content of registers,

(iii) slicing out specific bits from registers,

(iv) adding or subtracting from registers,

(v) complementing register contents,

(vi) transferring all or part of the contents of a register to another register,

(vii) storing in a register a satellite parameter whose format identification is contained in another register, and

(viii) sending commands, the pattern and number of bits to be sent being stored in two registers.

3.3.2 Call feature

The call box, as its name implies, is used as necessary to call other self-contained programs and then return to the place in the program from which it was called. This feature is used with 'return'. It is most commonly used during command sending phases where a verification that a command has been successful is performed by calling the appropriate verification program and then returning to the command phase for continuation of the main program. See Appendix D, Fig.D92.

3.3.3 Restore and save features

These are contained within the executive program. In the event of a hold up such as a temporary computer equipment fault during a pass, the contents of the registers, flags and times (stored in the set up phase or updated during the pass) at the time of the fault are stored on disc and can be restored when the program is restarted. Thus the correct status for the operational events are still available. This facility can, and has been, used during an actual pass with no loss of the status information held within the computer equipment, and illustrates the flexibility of the system design.

4 MIRANDA OPERATIONS

Miranda transmitted telemetry data at a rate of 2048b/s in split phase 'C' code and for a typical pass duration time of 15min, some 2×10^6 bits of data

were received by the CC. A total of approximately 1600 passes were monitored during the satellite's lifetime of nine months, during the course of which some 3×10^9 bits of data were received and processed.

There were only two occasions when the ground station and CC were unable to perform their role. Simultaneous unserviceability of the prime and back-up command stations caused the loss of three scheduled passes. On one occasion, high wind gusting exceeded the maximum safe operating limit for the ground station antennae and three scheduled passes were cancelled.

Shift working was necessary to cover the dawn and dusk periods of operation and the leader of each shift at the CC, the satellite controller, had an intimate knowledge of the satellite and was given executive authority for making operational decisions. The controller could operate with only one engineer/technician to assist him, but in practice, two were employed. This second man, responsible for operating the back-up command station antenna positioning controls during a pass, if required, helped the other in the routine processing work between passes, thus giving the satellite controller time to think. No shift personnel were computer specialists and only a knowledge of computer peripheral operating was required. At the CC, the total operations team consisted of eleven people, three of whom were satellite controllers. At the ground station, two people of engineer/technician grade were used for each shift and the team consisted of eight people.

Full details of the Miranda real time operations and programs can be found in Appendix D, and a typical teletype output in Appendix E.

5 EXPERIMENTAL OBJECTIVES

The planned programme of experimental work was completed satisfactorily in spite of time lost early in the life of the satellite due to erratic operation of the gas system.

The main programme consisted of operational experiments to determine the performance of the attitude control system (ACS) and of infra-red, albedo and star sensors. They were devised by the experimenters concerned and presented to the satellite controller for implementation. Integrated with these experiments were secondary tasks of both operational and technological interest. These were scheduled by the satellite controller in consultation with the sub-system designer concerned and were independent of the main programme.

5.1 Main experimental programme

The main experimental programme consisted of the following activities, many of them being run in parallel.

5.1.1 Attitude control system

(a) Determination of long term drift rate for each of the four gyros by periodical measurement until the satellite entered eclipse.

(b) Calibration of each of the prime rates of rotation about the pitch axis, 217, 12 and 8 degrees per hour (both positive and negative), and of the pitch integrator at five different positive and negative rates.

(c) Pulsing of each prime and redundant jet individually to establish system performance.

(d) Resolving the output of the back up skew gyro into each axis in turn.

(e) Testing each mode of operation.

5.1.2 Infra-red sensor experiment

Data were collected continuously from the experiment during the life of the satellite. Rotation about the pitch axis was controlled to achieve scans of selected areas of the earth, the horizon, and space (for calibration) at different detector gain settings.

5.1.3 Photo-diode array (albedo experiment)

Data were obtained continuously from the array using different levels of integrator setting. Additionally, these data provided attitude determination in support of other experiments.

5.1.4 Star sensor experiment

(a) Star lock

At suitable periods, a programme of timed pitch rate manoeuvres was initiated to culminate in lock of the sensor to a selected bright star. Good repetitive star lock of some 30min each were obtained on the stars Canopus, Vega and Sirius, reacquisition continuing for periods of days. Acquisition and repetitive lock on to Achernar was also achieved for a few hours. The sequence of events for achieving star lock is shown in Appendix G, Fig.G2.

(b) Star scan

Using the basic star lock sequence of operations, successful star scan was achieved by superimposing a square wave on the pitch rate. The effect of this was to rock about the pitch axis and scan the selected star.

(c) Star look

This is similar to star lock except that the satellite remains in inertial sun lock (Mode 3), the object being to pass the star sensor field of view across a selected star.

(d) Star mapping

In certain ACS modes and when performing other experiments, star mapping was carried out and many stars, down to magnitude 4 were identified.

(e) Calibration mode

In order to measure the degradation of the sensor with time, internal calibration (using a radio-active source) was periodically selected.

The analysis and results of the RAE experiments are reported elsewhere[5-7].

5.2 Secondary programme

5.2.1 AGC measurements

During certain pitch rate manoeuvres, signal strength measurements of the satellite telemetry transmissions were obtained by recording AGC levels of the ground station receivers. This enabled comparisons to be made between performance of the satellite aerials in orbit with polar diagrams plotted from measurements taken before launch.

5.2.2 Redundant circuits

Since Miranda was a technological satellite, it was desirable to gather as much information as possible about the performance of the various common user equipments. This includes the selecting and exercising of all on-board redundant units. In order not to jeopardise the main experiment programme, these tests were only performed when the satellite neared the end of its life. Some units, however, were selected when the two electronically disturbed passes occurred (see section 6.2).

5.2.3 Operational experiments

(a) Normally, each command to Miranda was transmitted from the ground using a five word format; i.e. two address and three execute words.

This repetition was intended to minimise the chances of a satellite failing to respond to commands. To check the integrity of the command system, a number of commands were sent in two word format (one address, one execute) with no failures.

(b) The response of the satellite command receivers was checked by recording the command receiver AGC levels while unmodulated carrier was transmitted from the ground.

6 EXPERIENCE IN USE

6.1 General

The method used for satellite operational control proved highly successful and more than 1600 orbits were monitored.

The requirements of the experimental programme was one of the major considerations in designing the operations system. That the programme was satisfactorily performed despite many changes from the original plan, demonstrates the flexibility of the RAE operations techniques. A period early in life, when the satellite experienced both gas system and electronic problems (briefly described in section 6.2) was successfully dealt with by the automatic control techniques. In particular, the problems associated with the two electronic disturbance passes would have been extremely cumbersome unless dealt with by a system capable of automatic remedial actions. It is unlikely that the diagnosis of faults and the setting up, sending and verification of the large number of remedial commands could have been done by manual techniques in the 12 minutes available.

The satellite controller on duty on each of these occasions was naturally under stress. However, his decision making was made easier by the availability of the pre-programmed diagnostic and automatic remedial action contingencies planned for such emergencies. He was relieved of the strain of working out the sequence of commands to correct the anomalies because, in general, his emergency actions were included in the suite of programs.

After each pass, the bit error rate was calculated by post pass programs automatically from information contained within the telemetry sum check. Figures for both direct and replay data were obtained and representative histograms are shown in Fig.2. During the operational life of Miranda, 91% of the passes received had direct data error rates of less than 1 in 10^5 bits and 31% had zero errors as measured at the CC.

The satellite tape recorder playback data figures for the same criteria were 45% and 3% respectively and 69% of the passes had error rates of less than 2 in 10^5 bits.

The reported figures are based on an analysis of data from 20% of the total operational passes evenly distributed from launch to end of life. The few occasions where gross error rates occurred, were identified at the time to be the result of ground equipment malfunction.

Reception by Miranda of ground commands has been excellent. Approximately 99.75% of commands sent to the satellite were received correctly first time and it should be noted that many commands were sent below the normally accepted 'safe command' horizon of 10^{o}. In many cases commands were sent and successfully received down to an elevation of 2^{o}.

The automation of operations, and remedial actions in particular, has a profound effect on the development of the satellite system and subsystems. Because of the lead time for the development of procedures and software, it is necessary for operations to be defined concurrently with the design of the subsystems. Failure mode analysis must be rigorous and it must be started early.

The imposition of these disciplines during the development of Miranda was entirely beneficial. The electrical tests carried out on the satellite during prototype qualification, flight verification and pre-launch testing were more representative of in-orbit conditions, and were consequently more effective than might otherwise have been the case. A number of anomalies* in the design and performance of the satellite which were not remedied by re-design, were detected sufficiently early for operational programs to be designed to deal with them. For example:

The 7 telemetry bits indicating gyro status instead of being contained within one 8 bit word, were separated; 4 bits in the ACS section of the format and 3 in the data handling section. The remaining bits of these 2 words contained data irrelevant to the gyro status.

Commands were not handled consistently within the satellite. The prime stop valve required transmission of a '1' to open it and a '0' to close it, while the redundant stop valve required transmission of a '0' to open it and a '1' to close it.

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* An anomaly is defined in this context as an unanticipated feature of system design, found during ground testing, which was considered not to warrant re-design.

There was no telemetry bit in the format to indicate reception of an execute command to ACS register A or B. Thus having filled the on-board register with the required instruction and verified this as correct, a failure to respond to that instruction could be due to either:

(a) Failure to receive the command to execute the register instruction, or

(b) having successfully received the execute command, the satellite failed to respond correctly to the register instruction.

6.2 <u>Electronic disturbance passes</u>

In the early part of the satellite's life there was a partial failure of the propane gas system (fully investigated by RAE and the subject of an internal report) and two passes during which there were major electronic disturbances[8]. It is not within the scope of this Report to describe these problems in detail, but a brief summary of the symptoms will give the reader a better understanding of how the operational techniques for Miranda enabled this difficult period to be overcome.

On the morning after launch (Day 69) the satellite appeared over the ground station's radio horizon transmitting data instead of unmodulated carrier. This was the first indication of unusual behaviour and subsequent automatic analysis of the data during the pass revealed the following changes from the expected status:-

(i) Mode changed to 8A and 9A simultaneously (an 'impossible' condition).

(ii) Gyro status - pitch gyro off, skew on, pitch resolved.

(iii) No fine sun sensor (FSS) presence.

(iv) A large yaw error was indicated.

(v) Data handling redundant circuits selected, viz analogue to digital converter (ADC) B, serial data stream B1 and tape recorder (TR) drive B.

(vi) Albedo experiment switched off.

(vii) Detector settings 3 and 4 of IR experiment changed.

(viii) Tape recorder A track 1 selected - tape recorder B expected.

(ix) Gas jet failure routine (GJFR) enabled.

(x) Replay data command was inhibited.

(xi) Reversion to mode 8 (emergency mode) on attempting to command mode 3 - the expected mode.

(xii) Redundant jets automatically selected by correct operation of the gas jet failure routine.

As each subsystem was checked, the operations software diagnosed the changes from the expected state. For those conditions previously defined as potential mission failure cases, remedial actions were automatically initiated by the operations software. Certain other remedial actions were initiated by the operator at the satellite controller's discretion. All problems were corrected during the time the CC was in contact with the satellite, approximately 12 minutes.

From this time onwards the gas system behaved erratically, presenting major operational control problems until it became clear what was causing the trouble. Pitch rates demanded by ground command invariably resulted in the gas regulator saturating and presenting excessively high gas pressure to the control jets which, by producing excessive thrust, caused rapid oscillations of the satellite. Additionally the redundant jets were often selected by the gas jet failure routine (see Appendix A).

During the early investigation it was sometimes necessary to send, verify and execute 3 multiple commands (up to 16 bits each) on satellite passes with a maximum elevation of only 7^{o}. As time progressed experience was gained in controlling the satellite to keep the gas pressure at the jets within manageable limits by using pitch axis orientation changes to increase system temperatures. This often involved transition through various modes to arrive at the required status. Remedial actions were worked out for implementation according to the problem. Without the flexibility, speed and integrity of the automatic control programs including the automatic emergency actions and the ability to interrupt and extemporize at any selected point in the program, it is very doubtful if the satellite could have been nursed successfully through this period.

A similar disturbed pass occurred 72 days later (Day 141) but from then onwards the gas system settled down and operated well enough for the Miranda experimental programme to proceed until the satellite finally ceased to function on or about 18 December 1974.

7 RECOMMENDATIONS

From the experience gained in planning and implementing the orbital operations, the following recommendations for future work of this nature are made.

7.1 Operations planning

7.1.1 Orbital operations staff should be represented from the earliest project meetings and their requirements considered throughout spacecraft design.

7.1.2 To achieve simplicity in the design of the automatic orbital operations programs the following are of particular significance:-

(a) Logical layout of telemetry format is required.

(b) Elimination of inconsistencies between actual on-board status and telemetered status.

(c) Provision of simple telemetry verification of satellite response to every valid command.

(d) Provision of an error detecting code within the format.

7.1.3 An orbital operations handbook should be produced early in the programme by the spacecraft prime contractor. It should define the spacecraft and its operation in sufficient detail for operational procedures and software to be developed and tested. The handbook should be continually amended as the programme is developed.

7.1.4 Analogue magnetic tape recordings of data from all spacecraft operational modes should be provided for proving operations procedures as soon as an integrated spacecraft exists.

7.1.5 A spacecraft, fully electrically representative of the flight model should be made available for final ground station and CC compatibility procedures and program proving trials. A time slot of not less than two weeks duration, at least three months before expected launch, must be planned for these activities.

7.1.6 Close liaison between the spacecraft AI & T team and the orbital operations planning team should be maintained as integration proceeds. This is important because it is during AI & T that the more obscure aspects of the spacecraft operation, which may be relevant to orbital operations, become apparent.

7.2 Operations

7.2.1 The visual display units (VDU) used to output satellite parameters for experimenters and subsystem designers should present the information directly in engineering units. For Miranda, arbitrary units in octal numbers were used for many parameters to economise on software.

7.2.2 The set up time required to input the requirements for each pass to the program should be reduced. For every pass it is necessary to input to the program the expected status of the satellite. This can become laborious and time consuming when many subsystems of the satellite remain unchanged for long periods. Shortening of the set up phase can be achieved by storing on computer backing store the current expected status of the satellite and updating changes to this status as necessary.

8 CONCLUSIONS

It is concluded that the use of efficient automatic techniques is more cost effective in terms of staff than the use of manual means. Apart from the satellite controller, comparatively junior staff can be employed (both in the preparation of the operations system and in its use) and total numbers reduced considerably. The techniques developed for Miranda have worked well, both for routine operations and during periods of satellite malfunction. The possibility of human error hazarding the mission has been virtually eliminated.

Satellite passes with a maximum elevation of only 7° (pass duration of the order of 8 minutes) have been monitored and ACS commands (register filling) successfully sent, verified and executed.

The use of automatic control techniques necessitates very early discussions between the operations staff, experimenters and subsystem designers which are mutually beneficial. The diagnosis of and remedial actions for certain possible fault conditions can be agreed and programmed. These possible faults can influence the philosophy of testing of the satellite during assembly, integration and test (AI & T).

The reported work further advances the RAE aim of achieving the maximum possible safety of the satellite in orbit and enabling fast and pre-planned means of implementing the in-orbit operations programme. It is considered that a system containing features of the type used for both Prospero and Miranda in-orbit operations could be used with advantage to control the operations of other satellites.

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Appendix A

THE MIRANDA SATELLITE

A.1 Brief description

Miranda, the second satellite in the British National Space Technology Programme was designed to prove in orbit techniques, components and materials for use in future spacecraft. The satellite which weighed 100kg was stabilised in three axes. The yaw and roll axes were maintained sun pointing to activate the solar array panels and the pitch axis was controlled in both rate and position as necessary to achieve the experimental objectives. The satellite contained five experiments and a set of common user equipment.

A.2 Common user equipment

A.2.1 Attitude control system (ACS)

Although the ACS was a fundamental part of the satellite and therefore could be classified as common user equipment, it was also the prime experiment and is described in detail in section A.3.

A.2.2 Data handling subsystem

The pulse code modulation (PCM) system consisted of a clock and divider chain driving a single encoder (multiplexer) which sampled the various data points in the sequence shown by the format (Fig.A1) for either real time transmission or on-board recording. The analogue voltages from each data point were routed to an ADC for conversion to a digital form suitable for modulation of the transmitter. The satellite contained a redundant clock, divider chains and ADC which could be selected by command.

A.2.3 RF subsystem

This system, operating at VHF, consisted of a telemetry transmitting unit and command receiving and decoding units.

The transmitter carrier frequency of 137.44MHz was phase modulated by the PCM split phase 'C' data waveform when commanded by the ground station to the direct data mode. Transmitted power output was approximately 300mW. A redundant transmitter was provided which could be selected by command. The command system, operating at 148.25MHz followed the NASA tone digital standard and consisted of a pair of receivers predominantly responsive to RHC and LHC polarisation respectively and two decoders each activated by its own unique address word.

Failure of either receiver or decoder would not effect operation of the remainder.

Both transmitter and receiver operated through a common hybrid and four element turnstyle array giving near omnidirectional communication capability.

A.2.4 Power supply

65W of power was provided by 1800 solar cells mounted on the two flexible panels, one on each side of the structure. These panels were deployed after launch by pressurised gas stored within their telescopic support arms. A small battery of 3AH capacity was fitted to power the satellite during launch and sun acquisition. The power conditioning subsystem was similar to that used on PROSPERO. It produced stabilised rails at ±5V and ±12V and two special tape recorder supplies from the raw solar array output.

Incorporated within this subsystem were three switches controlling the power supply to experiments B, C and D.

A.2.5 Tape recorders

Since the X4 operations were carried out by only one ground station full orbit data coverage could only be obtained by recording on board the satellite and dumping data during a pass over the ground station. Two tape recorders were carried, only one being operated at a time; they operated on a two week cycle until failure of tape recorder B after five months. The data were recorded in a format identical to that transmitted in real time but at a slower bit rate (record = 64b/s, real time = 2048b/s).

Since only one encoder was available, simultaneous recording and real time data transmission were not possible and for this reason real time data were only available on command when in range of the ground station.

A.3 Experiments

A.3.1 ACS (experiment A)

The attitude control inertial reference was provided by three integrating rate gyros: in the roll and yaw axes it was updated by a sun sensor. Control torquing was provided by propane gas jets. The control logic incorporated an electronic analogue model for the satellite dynamics which yielded a high quality estimate of the attitude rate[9]. The whole system was aimed at achieving relatively small pointing errors without undue expenditure of gas.

A fourth skew gyro was included, the output of which could be resolved to replace any one of the orthogonal gyros in the event of failure.

A fine sun sensor (FSS) provided position information of the yaw and roll axes related to the sun and could be selected by ground command. The coarse reference using the prime sun sensor (PSS) could be selected by ground command or automatically if back-up modes were entered. The pitch axis rotation rate could be controlled by ground command selection of integrator and/or prime rates.

The experimental star sensor (experiment C) could also be used to control the pitch axis to achieve star scan or lock (described later).

The gas system producing the control torques consisted of a pressure tank containing liquified propane, a high pressure reduction valve, a boiling coil and a low pressure reduction valve. Two stop valves controlled the flow of gas to either the six prime or six redundant jets. Combinations of these jets could be selected by ground command.

Additionally, the satellite contained an automatic gas jet failure routine (GJFR) which continuously monitored the amount of gas used by the jets and automatically selected the redundant jets and closed the prime stop valve if more than an aggregate of 4 seconds expulsion of gas occurred in 128 seconds. The GJFR was inhibited in some ACS operating modes.

The ACS subsystem had ten modes of operation, nine of which could be selected by ground commands (Mode 5 could be subdivided into two modes, only one of which could be selected by ground command). Modes 8 and 8A, could also be initiated automatically by the satellite in response to certain conditions, e.g. loss of fine sun presence when selected to fine sun sensor. The ten modes of operation were:

(1) Mode 2 - Sun acquisition

This mode was used initially after despin and separation to orientate the satellite such that the yaw and roll axes were sun pointing. In this mode, because large amounts of gas could be used, the GJFR and automatic selection of Mode 8 were inhibited. The yaw and roll axes were controlled by their respective gyros which were fed by the PSS output. Secondary sun sensors provided 360° acceptance angle for initial acquisition. The gyros operated in the rate mode. After initial acquisition this mode could be entered only by ground command.

(2) Mode 3 - Inertial sun lock

This was the most commonly used mode in which the FSS output updated the yaw and roll gyros operating in the rate integrating mode. Rates about the pitch axis could be controlled in this mode using the prime and/or pitch integrator.

(3) Mode 3A - Back-up inertial sun lock

Similar to Mode 3, but used the prime sun sensor and back-up circuits.

This was the control mode used extensively during the early orbit phase when gas system malfunctions occurred, to reduce gas consumption by increasing the width of the dead band (the boundary which controls jet pulsing).

(4) Mode 4 - Earth reference

Similar in operation to Mode 3, but with a $\pm 12^{o}$/h square wave superimposed on an orbit rate of 217^{o}/h, i.e. this rate caused the satellite to rotate and rock about the pitch axis.

(5) Mode 5 and 5A - Star search and lock

In this mode the experimental star sensor was used to control the pitch axis and lock it to a selected star. The sequence was initiated in Mode 3 during a morning pass (see Fig.F2) when a pre-alignment rate calculated to achieve star presence the following evening was commanded at a predetermined time. On the first pass of the evening (E1), the rate value contained in the pitch integrator was cancelled, Mode 5 selected and a prime rate of $\pm 20^{o}$/h (depending on star selected) commanded at a predetermined time.

During the next pass (E2), the star presence 'bit' was monitored from replay data and if 'up', and the star lock trigger pulse set, Mode 5A was indicated.

If this occurred, the prime rate of 20^{o}/h would have been removed and the output of the experimental star sensor would have updated the pitch axis control loop via the pitch integrator. When star presence was lost, the output of the star sensor was removed automatically and the pitch axis maintained at that orientation until star presence was reobtained on the next orbit.

In the event of star presence for less than a period of time equivalent to 30 minor frames, Mode 3 was reselected by ground command, this being an automatic feature.

(6) Mode 6 - Star scan

This mode could be entered only after achieving star lock in Mode 5A. Operation was as for Mode 3 except that a square wave $\pm 8^{o}/h$ pitch rate was imposed so that the star sensor would scan across the previously acquired star.

(7) Mode 8 - Emergency sun acquisition

This mode was entered automatically (or by ground command) for the following reasons:

(a) If the transfer from prime to redundant jets by the GJFR did not remove the high duty cycle if present in the yaw or roll axis.

(b) Loss of FSS presence signal.

The gyros operated in the rate mode and the yaw and roll axes were controlled directly by the prime sun sensor. Any rate applied about the pitch axis was removed automatically. Modes 2 and 8A were inhibited.

(8) Mode 8A - Emergency pitch acquisition

This mode was entered automatically (or by ground command) if the transfer from prime to redundant jets by the GJFR did not remove the high duty cycle if present in the pitch axis. The yaw and roll gyros remained selected but the skew gyro was then powered and resolved to the pitch axis. The prime sun sensor was selected and Modes 2 and 8 inhibited.

(9) Mode 9A - Back-up earth reference mode

In this mode the yaw and roll axes were controlled directly by the PSS. Control of the pitch axis was via back-up circuits.

A.3.2 Infra-red sensor (experiment B)

This was an experimental sensor, designed and built by RAE, of a type that could be used for future earth pointing satellites. The object of the experiment was to test the sensor's performance in space and to monitor the characteristics of the infra-red horizon. In addition, it provided a warning when the field of view of the star sensor (experiment C) approached eclipse by the earth and also provided data for attitude determination. The gain settings of the four IR detectors could be changed by ground command.

A.3.3 Star sensor (experiment C)

This experimental sensor was designed and built by RAE to test in orbit a device which could be used in future spacecraft to position an axis relative to a preselected star. It consisted basically of a stepper mirror, optical system, an image dissecting photo-multiplier and an electronics unit. The five main objectives of the experiment were:

(1) To check the accuracy of the photometric calibration of the star sensor using the (A_0) star Vega.

(2) To measure the launch and space environmental effects on the sensor.

(3) To investigate any effects that the expelled propane gas may have on the sensor optics.

(4) To demonstrate the method and accuracy of star acquisition and lock that can be achieved in the control of the satellite about the pitch axis.

(5) To provide accurate pitch attitude reference.

Ground commands associated with this experiment were to adjust the mirror position to take into account the elongation angle of the particular star, the gain of the sensor to accept stars of different magnitudes and to select as required a built in calibration source. It was also possible to override the eclipse warning from the IR sensor by command.

A.3.4 Albedo sensor (experiment D)

The RAE albedo sensor was designed and built to demonstrate operation in orbit of a self scan 100 element photodiode array which in future spacecraft could be used as a sun or albedo sensor. In Miranda it was used as an albedo sensor and provided additional information in support of the other experiments. Ground command of this experiment was limited to selection of the required sensitivity.

A.3.5 Solar array patches (experiment E)

This experiment tested the performance of new thin lightweight solar cells and did not supply power to the satellite. It consisted of two patches, one on each of the main array panels. Their temperature sensors served to indicate the temperature of the main array. No commands were associated with this experiment.

A.3.6 Electronic assembly

The electronic circuits used in the RAE experiments were assembled using a particular form of thick film hybrid construction developed at RAE and called Multi Chip Integration (MCI). Although orbited experimentally in Prospero to prove its suitability for space use, this was the first operational application of the technique.

A.4 Telemetry format

A single format, conforming to NASA standards, was generated for both recording purposes and for direct data transmission. Details are as follows:-

Modulation	:	PCM
Code	:	Split phase 'C'
Bits/word	:	8
Words/minor frame	:	128
Minor frames/major frame	:	8
No. of bits in Sync code pattern	:	23
Data quality word (sum check) (No. of bits)	:	8

		Direct and playback data	Recorded data
Bit rate	:	2048b/s	64b/s
Word rate	:	256/s	8/s
Minor frame rate	:	2/s	1/16s
Major frame rate	:	1/4s	1/128s

Note: The word slots in the format are numbered in octal base, i.e. 000 to 177 for the 128 words in a minor frame. Sub-commutated channels, i.e. words that occur at major frame rate, are identified by the addition of the minor frame number in front of the word number. Minor frames are numbered 0 to 7, e.g. 3/044 means word 044 in the fourth minor frame. Sampling rates other than prime or major frame rate are used for certain parameters.

Table A1 gives the full telemetry list and Fig.A1 the format.

A.5 Command system

The satellite command system receives and acts upon 70 different tone-digital commands conforming to NASA Standards. Details are as follows:-

Carrier frequency	:	148.25MHz	
Sub. carrier frequency	:	7.0kHz	
Modulation	:	PDM/AM/AM	
Satellite decoder address:		Decoder A	Decoder B
		10110111	00001001

A.5.1 List of commands

The 70 commands available are divided between housekeeping, ACS and experiments as follows:-

Housekeeping:		
(a)	Data handling	27
(b)	Power conditioning	10
ACS		19
Experiments		14

A.5.2 ACS register stored commands

General

The Miranda ACS required up to 16 commands to be sent to the register (plus one to select register 'A' or 'B'). The LSB is transmitted first and each bit is shifted one place to the right by the arrival of the next. When the contents of the selected register has been checked from telemetry data, an execute command is transmitted. This command does not clear the register so that if the execute fails, it may be repeated.

Only command numbers 40 (logic level '0' select), and 42 (logic level '1' select) may be used to fill register 'A'. Similarly, only command numbers 41 and 43 ('0' and '1' respectively) may be used to fill register 'B'.

A.5.2.1 Command register

ACS stored commands in each command register contains up to 16 bits as shown below

MSB															LSB
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

Fourteen basic commands are used and are given in Table A2.

A.5.3 Direct commands

A description of the 70 commands allocated are given in Table A3.

Table A1

Telemetry format description

Param Ref.	Word slot	Data rate	Description
Sync	000	2/s	11110101
Sync	001	2/s	11001101
Sync +1	002	2/s	00000001
DD00	004	2/s	Frame ident clock output first 8 bits. Increments one per frame. First 3 bits indicate minor frame. LSB first.
DD11] DD14]	005	2/s	Frame ident clock out - last 4 bits of 12 bit frame counter.
DD15			Bit 5 Tape recorder off. Indicated by 1.
DD16			Bit 6 Separation interlock present. Indicated by 1. (In orbit goes to '0')
DD17			Bit 7 High speed data enable. Goes to 0 when direct mode is commanded. Seen as a '1' during playback.
DD18			Bit 8 tape recorder control 1. Always at '1'. (Goes to '0' in PB therefore '0' is never seen.)
DD21	103	2/s	Bit 1 Tape recorder control 2. Goes to '0' for record only, therefore seen as '1' in direct data mode and as '0' in PB mode.
DD22			Bit 2 Tape recorder A selected. Indicated by '1'.
DD23			Bit 3 Tape recorder B selected. Indicated by '1'. Both go to '1' when both are selected. (Launch mode.)
DD24			Bit 4 Tape recorder data stop. Indicated by '1'. (Tape recorder will still be running during direct data mode therefore seen as '1', and as '0' in playback.
DD25			Bit 5 Track ident 1 } Read together for indication
DD26			Bit 6 Track ident 2 } of which track is recording. Track 1:00, track 2:10, track 3:01, track 4:11.
DD27			Bit 7 Record enable. Indicated by '1' in PB. Is at '0' in direct data mode.
DD28			Bit 8 Playback enable.
DD31	006	2/s	Bit 1 Clock source A/B: A = 0, B = 1
DD32			Bit 2 Divider chain A_1/B_1: A = 0, B = 1
DD33			Bit 3 Divider chain A_2/B_2: A = 0, B = 1
DD34			Bit 4 ADC A/B A = 0, B = 1
DD35			Bit 5 Serial data stream A_1/B_1: A = 0, B = 1
DD36			Bit 6 Serial data stream A_2/B_2: A = 0, B = 1
DD37			Bit 7 Tape recorder drive A/B: A = 0, B = 1
DD38			Bit 8 Tape recorder router A/B: A = 0, B = 1

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
DD41	007	2/s	Bit 1 Record track 1. Goes to 1 when selected
DD42			Bit 2 Record track 2. Goes to 1 when selected
DD43			Bit 3 Record track 3. Goes to 1 when selected
DD44			Bit 4 Record track 4. Goes to 1 when selected
DD45			Bit 5 Playback track 1. Goes to 1 when selected
DD46			Bit 6 Playback track 2. Goes to 1 when selected
DD47			Bit 7 Playback track 3. Goes to 1 when selected
DD48			Bit 8 Playback track 4. Goes to 1 when selected
DD51	100	2/s	Bit 1 Transmitter selected A/B: A = 1, B = 0
DD52			Bit 2 ADC input A. Indicated by 1
DD53			Bit 3 ADC input B. Indicated by 1
DD54			Bit 4 Tape recorder A moving
DD55			Bit 5 Tape recorder B moving Whichever tape recorder is moving is indicated by changing state but a minimum of four frames of data is required to see the change. No change of state indicates that T.R. is not moving.
DD56			Bit 6 ACS override. '1' indicates that the ACS tape recorder stop facility has been overridden by command 1 and can be reset only by sending a T.R. router change command.
DD57			Bit 7 +X solar array deployed '0' = deployed
DD58			Bit 8 -X solar array deployed '1' = not deployed
PD01	101	2/s	Bit 1 User switch 1 Experiment B ON/OFF. 1 indicates ON
PD02			Bit 2 User switch 2 Experiment C ON/OFF 1 indicates ON
PD03			Bit 3 User switch 3 Experiment D ON/OFF. 1 indicates ON
PD04			Bit 4 Battery charge main/trickle. '1' indicates high rate of charge
PD05			Bit 5 Thermal relay ON/OFF. Goes to 1 when thermal relay is closed, i.e. temp below 32°C. Goes to '0' when thermal relay opens, i.e. temp is above 35°C or when the trickle charge command has been sent and PD04 is at a '0'. Bits 6,7 and 8 are used for ACS command verification and are listed in Table 2.
DD60	003	2/s	Sumcheck. Displays 8 LSBs of a 'ones' count from start of word 004 to end of word 002.

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
CD01	025	2/s	Bit 1 Satellite separation. 1 indicates separated.
CD02			Bit 2 Deploy array. 1 indicates deploy signal has been generated.
CD03			Bit 3 Stop tape recorder. 0 indicates T.R. stop has been generated (present for only 64s)
CD04			Bit 4 Star presence. 0 = TRUE
CD05			Bit 5 Star lock 1 = TRUE
CD06			Bit 6 PSS to FSS change over { 1 = FSS, 0 = PSS
CD07			Bit 7 Primary sun sensor output. 0 indicates presence of sun.
CD08			Bit 8 Fine sun sensor output. 0 indicates presence of the sun
CD11	020	4/s	Bit 1 Gas jet failure inhibit. 0 = INHIBITED; 1 = ENABLED. (Set by command only.)
CD12	120		Bit 2 Roll gyro. 0 = ON 1 = OFF
CD13			Bit 3 Yaw gyro 0 = ON 1 = OFF
CD14			Bit 4 Pitch gyro 0 = ON 1 = OFF
CD15			Bit 5 Skew gyro 0 = ON 1 = OFF (*see footnote)
CD16			Bit 6
CD17			Bit 7 Horizon detector 2 0 = ALBEDO PRESENT
CD18			Bit 8 Horizon detector 1 0 = ALBEDO PRESENT
CD20	026	2/s	Gas jet and stop valve status
CD21			Bit 1 Redundant stop valve 1 = OPEN 0 = CLOSED
CD22			Bit 2 Prime stop valve 1 = OPEN 0 = CLOSED
CD23			Bit 3 Yaw -ve gas jet 0 = PRIME 1 = REDUNDANT
CD24			Bit 4 Yaw +ve gas jet 0 = PRIME 1 = REDUNDANT
CD25			Bit 5 Pitch -ve gas jet 0 = PRIME 1 = REDUNDANT
CD26			Bit 6 Pitch +ve gas jet 0 = PRIME 1 = REDUNDANT
CD27			Bit 7 Roll -ve gas jet 0 = PRIME 1 = REDUNDANT
CD28			Bit 8 Roll +ve gas jet 0 = PRIME 1 = REDUNDANT
			NOTE: Bits 3 to 8 are irrelevant when both stop valves are closed.
CD30	021	4/s	Mode status. If all 8 bits are at 0 then the mode is 3. Eight other modes are indicated by the presence of a 1 as follows:
CD31			Bit 1 Mode 3A
CD32			Bit 2 Mode 9A
CD33			Bit 3 Mode 8A
CD34			Bit 4 Mode 8
CD35			Bit 5 Mode 6
CD36			Bit 6 Mode 5
CD37			Bit 7 Mode 4
CD38			Bit 8 Mode 2
			NOTE: If bits 6 and 8 are both 1, then the Mode is 5A.

* CD15 not necessarily true in mode 8A.

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
PD06 PD07 PD08	101	2/s	Bit 6 Pitch gyro resolved output Bit 7 Yaw gyro resolved output Bit 8 *Roll gyro resolved output* '1' indicates 'resolved'
CR01	065	2/s	Gas jet monitor reference and number of demands. First 5 bits are used to count number of demands (11111 indicates 31). This count is reset every 16s unless Cmd 109 is sent when the scan is stopped and the number of demands on one jet is monitored until receipt of Cmd 110. Next 3 bits used to identify which of 6 jets is being monitored, viz: Bit 6 Bit 7 Bit 8 Pitch +ve 0 0 0 Pitch -ve 0 0 1 Yaw +ve 0 1 0 Yaw -ve 0 1 1 Roll +ve 1 0 0 Roll -ve 1 0 1
CR02	066	2/s	Gas jet monitor First 4 bits used for 'GAS CONSUMPTION'. These 4 bits are the MSBs of a 15 bit counter, the resolution of which is 1ms. It will reset when the count exceeds 32.767s. Bits 5 to 8: demanded ON time, 4 MSBs. The demanded ON time counter is reset every 16s. The MAX count represents 4.095s.
CR03	067	2/s	Gas jet monitor. Demanded on time, 8 LSBs
CR04	022 122	4/s	Integrator outputs, pitch, 7 LSBs, plus sign (bit 8) NOTE: All '0's is MAX count
CR05	023 123	4/s	Integrator outputs, yaw, 7 LSB, plus sign 1 = +ve NOTE: All '0's is MAX count
CR06	024 124	4/s	Integrator output, roll, 7 LSBs, plus sign NOTE: All '0's is MAX count
CR15	125	2/s	Integrator outputs, pitch, 5 MSBs, plus sign (bit 8) (Bits 1 and 2 not used) NOTE: All '0's is MAX, count
CR16	126	2/s	Integrator outputs, yaw, 4 MSBs, plus sign 1 = +ve (Bits 1, 2, 3 not used) NOTE: All '0's is MAX count
CR17	127	2/s	Integrator outputs, roll, 4 MSBs, plus sign (Bits 1, 2, 3 not used) NOTE: All '0's is MAX count

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
CR09	060	2/s	Command register A, 8 MSBs
CR10	061	2/s	Command register A, 8 LSBs
CR11	062	2/s	Command register B, 8 MSBs
CR18	063	2/s	Command register B, 8 LSBs
CR12	027	2/s	Gas jet failure 3 bits are used to indicate the axis in which the failure has occurred. Bits 1 to 5 not used. Bit 6 yaw, 0 = FAILURE, 1 = OK Bit 7 roll, 0 = FAILURE, 1 = OK Bit 8 pitch, 0 = FAILURE, 1 = OK
ED00 ED01 to ED04	104	2/s	Canopus star sensor mirror position: 12 positions. Bits 1 to 4 define mirror position as follows: Position — Bit pattern 1 — 0 0 1 1 2 — 0 0 0 1 3 — 0 1 0 1 4 — 0 1 1 1 5 — 1 1 1 1 6 — 1 0 1 1 7 — 1 0 1 0 8 — 1 1 1 0 9 — 0 1 1 0 10 — 0 1 0 0 11 — 1 1 0 0 12 — 1 1 0 0 (Not different from 11)
ED05 ED06			Bits 5 and 6 Threshold setting 25% — 1 0 50% — 0 1 100% — 1 1 200% — 0 0
ED07			Bit 7 Override eclipse warning: command status: 1 = override
ED08			Bit 8 Calibrate: 1 = calibrate
ED10 ED11	105	2/s	Infra-red sensor status Bits 1 and 2 are used to indicate the gain of detector 4
ED12			The gain is changed by toggle commands 61 and 59. Bit 1 state is changed by reception of command 61. Bit 2 state by command 59. 100% gain — 1 1 93% — 1 0 86% — 0 1 79% — 0 0

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
ED13	105	2/s	Bits 3 and 4 are used to indicate the gain of detector 3 and the status of toggle commands 58 and 57. (Cmd 58 sets bit 3, cmd 57 sets bit 4.) 100% 1 1 93% 1 0 86% 0 1 79% 0 0
ED15			Bit 5 Duplicate of bit 1
ED16			Bit 6 Deplicate of bit 3
ED17			Bit 7 Eclipse warning to Expt C 1 indicates star sensor output in valid 0 indicates that star sensor must be taken out of ACS control loop if it is included.
ED18			Bit 8 Duplicate of bit 7
ED20	106	2/s	7 frames of data are required for a complete read-out of data from the 100-element array Albedo sensor.
ED30	107	2/s	However, 8 frames are used as follows so that data samples are tied to major frame rate. During the first minor frame the 16 bits of ED20 and ED30 contain 12 bits of housekeeping data, (read-out first), and the first 4 read-outs from the 100-element array. The next 6 minor frames are used to read-out the rest of the 100-element array*. During the 8th minor frame ED20 and ED30 contain the first 16 bits of the array read-out again.

* The table below gives the bit description of the first minor frame.

Param Ref.	Word slot	Data rate	Description
ED20	0/106	1/4s	
ED21			1ms integration period } Only ONE is possible at any one time.
ED22			4ms integration period
ED23			16ms integration period
ED24			+12V monitor. Logic 1 is correct
ED25			-12V monitor. Logic 1 is correct
ED26 to ED28			Data pulse monitor. Logic 1 is correct
ED30	0/107	1/4s	
ED31 to ED33			Data pulse monitor. Logic 1 is correct
ED34			+5V monitor. Logic 0 is correct
ED35 to ED38			First 4 read-outs from the 100 element array

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
DP01	0/141	1/4s	Command receiver A: AGC level
DP02	1/141	1/4s	Command receiver B: AGC level
DP03	2/141	1/4s	Transmitter: power output. Selected Tx
DP04	4/141	1/4s	Pressure: tape recorder A. Ambient pressure within the TR container
DP05	5/141	1/4s	Pressure: tape recorder B. Ambient pressure with the TR container
DP06	6/141	1/4s	Thermistor reference. Nominal, +2.7V
DP07	7/141	1/4s	Not allocated
DP08	0/142	1/4s	ADC A: positive calibration level, +2.5V
DP09	1/142	1/4s	ADC A: negative calibration level, -4.7V
DP10	2/142	1/4s	ADCs: common zero calibration level, nominal 0V
DP11	3/142	1/4s	ADC B: positive calibration level, +2.5V
DP12	4/142	1/4s	ADC B: negative calibration level, -4.7V
DT05	4/143	1/4s	Tape recorder A: temperature
DT06	5/143	1/4s	Tape recorder B: temperature
PT01	5/142	1/4s	Battery temperature
PT02	6/142	1/4s	Power: regulation and distribution unit, temperature
PT03	7/142	1/4s	Power convertor unit, temperature
PC01	0/144	1/4s	Power conditioning: current monitor, +12 volts regulated output
PC02	1/144	1/4s	Current monitor, -12 volts regulated output
PC03	2/144	1/4s	Current monitor, +5 volts regulated output
PC04	3/144	1/4s	Current monitor, -5 volts regulated output
PC05	4/144	1/4s	Current monitor, +12 volts tape recorder supply regulated output
PC06	5/144	1/4s	Current monitor, -12 volts tape recorder supply regulated output
PC07	6/144	1/4s	Current monitor: battery
PC08	7/144	1/4s	Current monitor: raw array bus
PV01	0/145	1/4s	Power conditioning: voltage monitor, +12 volts regulated output
PV02	1/145	1/4s	Voltage monitor, -12 volts regulated output
PV03	2/145	1/4s	Voltage monitor, +5 volts regulated output
PV04	3/145	1/4s	Voltage monitor, -5 volts regulated output

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
PV05	4/145	1/4s	Voltage monitor, +12 volts tape recorder supply regulated output
PV06	5/145	1/4s	Voltage monitor, −12 volts tape recorder supply regulated output
PV07	6/145	1/4s	Voltage monitor: battery
PV08	7/145	1/4s	Voltage monitor: raw array bus
ST01	0/146	1/4s	Structure temp. 1, +Y panel, centre lower section
ST02	1/145	1/4s	Structure temp. 2, +Y panel, centre upper section
ST03	2/146	1/4s	Structure temp. 3, +Y panel, lower section
ST04	3/146	1/4s	Structure temp. 4, −X panel, lower section
ST05	4/146	1/4s	Structure temp. 5, −X panel, upper section
ST06	5/146	1/4s	Structure temp. 6, −Y panel, centre lower section
ST07	6/146	1/4s	Structure temp. 7, strong ring
ST08	7/146	1/4s	Structure temp. 8, botton floor
ST09	3/143	1/4s	Structure temp. 9, top floor
CG01	010 030 050 070 110 130 150 170	16/s	Gyro output: pitch
CG02	011 031 051 071 111 131 151 171	16/s	Gyro output: yaw
CG03	012 032 052 072 112 132 152 172	16/s	Gyro output: roll

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
CG04	013 033 053 073 113 133 153 173	16/s	Model, estimate of spacecraft rate: pitch
CG05	014 034 054 074 114 134 154 174	16/s	Model, estimate of spacecraft rate: yaw
CG06	037 137	4/s	Model, estimate of spacecraft rate: roll
CS01	035 135	4/s	Fine sun sensor output: yaw
CS02	036 136	4/s	Fine sun sensor output: roll
CP01	015 115	4/s	Estimate of spacecraft disturbing torques: pitch
CP02	016 116	4/s	Estimate of spacecraft disturbing torques: yaw
CP03	017 117	4/s	Estimate of spacecraft disturbing torques: roll
CG07	055 155	4/s	Skew gyro output
CP04	157	2/s	Gyro (pitch) torquing signal
CP05	164	2/s	Gyro (yaw) torquing signal
CP06	165	2/s	Gyro (roll) torquing signal
CS03	056	2/s	Secondary sun sensor output: yaw
CS04	057	2/s	Secondary sun sensor output: roll
CS05	075	2/s	Primary sun sensor output: yaw
CS06	076	2/s	Primary sun sensor output: roll
CP11	161	2/s	Model estimate of spacecraft position: pitch
CP12	162	2/s	Model estimate of spacecraft position: yaw
CP13	163	2/s	Model estimate of spacecraft position: roll

Table A1 (continued)

Param Ref.	Word slot	Data rate	Description
CP08	5/044	1/4s	Tank pressure
CP09	6/044	1/4s	Gas pressure after first reduction valve
CP10	7/044	1/4s	Gas pressure after second reduction valve
CT01	0/041	1/4s	Gyro temperature roll
CT02	1/041	1/4s	Gyro temperature yaw
CT03	2/041	1/4s	Gyro temperature pitch
CT04	3/041	1/4s	Gyro temperature skew
CT05	4/041	1/4s	Fine sun sensor temp
CT06	5/041	1/4s	Primary sun sensor temp
CT07	6/041	1/4s	Horizon detector 1
CT08	7/041	1/4s	Electronics unit temp
CT09	0/042	1/4s	Tank temp. 1. Liquid/gas outlet
CT10	1/042	1/4s	Tank temp. 2. Tank upper flange
CT11	2/042	1/4s	Tank temp. 3. Start of boiler coil
CT12	3/042	1/4s	Tank temp. 4. Tank upper dome
CT13	4/042	1/4s	Tank temp. 5. Middle boiler coil
CT14	5/042	1/4s	Tank temp. 6. Tank lower dome
CT15	6/042	1/4s	Tank temp. 7. End boiler coil
CT16	7/042	1/4s	Tank temp. 8. Tank lower flange
CT17	0/043	1/4s	Tank temp. 9. Liquid regulator body
CT18	1/043	1/4s	Tank temp. 10. Gas regulator body
CT19	2/043	1/4s	Gas jet 1 temp. Pitch +ve
CT20	3/043	1/4s	Gas jet 2 temp. Pitch -ve
CT21	4/043	1/4s	Gas jet 3 temp. Yaw +ve
CT22	5/043	1/4s	Gas jet 4 temp. Yaw -ve
CT23	6/043	1/4s	Gas jet 5 temp. Roll +ve
CT24	7/043	1/4s	Gas jet 6 temp. Roll -ve

Table A1 (concluded)

Param Ref.	Word slot	Data rate	Description
ES01	077 177	4/s	Infra-red detector 1
ES02	0/147 2/147 4/147 6/147	1/s	Infra-red detector 1-2
ES03	1/147 3/147 5/147 7/147	1/s	Infra-red detector 2
ES04	0/045 4/045	1/2s	Infra-red detector 3
ES05	1/045 5/045	1/2s	Infra-red detector 4
ES08	2/143	1/4s	Infra-red detector 3-4
ET01	2/045	1/4s	Infra-red sensor temp. (Detector assembly)
ET02	3/045	1/4s	Infra-red sensor temp. (Lens assembly)
EP03	6/045	1/4s	Infra-red sensor. Chopper amplitude
ES06	046 166	4/s*	Canopus star sensor magnitude
ES07	047 167	4/s*	Canopus star sensor nulling
EP04	176	2/s	Canopus star sensor EHT voltage
ET03	3/141	1/4s	Canopus star sensor temp.
ET04	7/045	1/4s	Albedo sensor temp.
EP01	0/044	1/4s	Solar array patch 1 voltage
EP02	1/044	1/4s	Solar array patch 2 voltage
ET05	6/143	1/4s	Solar array patch 1 temp.
ET06	7/143	1/4s	Solar array patch 2 temp.

* Not symmetrical in the format

Table A2

ACS register commands

Description	A	B	C	D	E	Verification
Pitch integ. bias	0	0	0			CR04 and CR15
Gas jet control reg.	0	0	1			CD20
Gyro status	0	1	0			CD12, 13, 14, 15, PD06, 07, 08
Pitch rate demands	0	1	1			CP04, 05, 06
Mode change	1	0	0			CD30
Gas jet exercise	1	0	1			Gyro output change
Gas jet failure inhibit	1	1	0	0	0	CD11, 0 = TRUE
Gas jet failure reset	1	1	0	0	1	CD11, 1 = TRUE
Stop jet monitor scan	1	1	0	1	0	Complex analysis
Start jet monitor scan	1	1	0	1	1	Complex analysis
Primary sun sensor select	1	1	1	0	0	CD06, 0 = TRUE
Fine sun sensor select	1	1	1	0	1	CD06, 1 = TRUE

Description of commands

(a) Command: pitch integrator bias

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
0	0	0	X	X	X	X	X	X	X	X	X	X	X	X	X

D = sign bit, 1 = positive.

12 bit register permits a maximum bias of 8.333×10^{-3} degrees per second.
Verification: CR04 and CR15.

(b) Command: gas jet control register

Description	D	E	F	G	H	I	J	K	Verification
Pitch positive prime	1	0	0	0	0	0	0	0	CD26
Pitch negative prime	0	1	0	0	0	0	0	0	CD25
Yaw positive prime	0	0	1	0	0	0	0	0	CD24
Yaw negative prime	0	0	0	1	0	0	0	0	CD23
Roll positive prime	0	0	0	0	1	0	0	0	CD28
Roll negative prime	0	0	0	0	0	1	0	0	CD27
Stop valve prime open	0	0	0	0	0	0	1	0	CD22
Stop valve redt. closed	0	0	0	0	0	0	0	1	CD21

Table A2 (continued)

(c) Command: gyro status register

Description	D	E	F	G	H	I	J	K	L	M	N	Verification
Pitch gyro off	1	0	0	0	0	0	0	0	0	0	0	CD14
Yaw gyro off	0	1	0	0	0	0	0	0	0	0	0	CD13
Roll gyro off	0	0	1	0	0	0	0	0	0	0	0	CD12
Skew gyro off	0	0	0	1	0	0	0	0	0	0	0	CD15
Pitch gyro high power	0	0	0	0	1	0	0	0	0	0	0	None
Yaw gyro high power	0	0	0	0	0	1	0	0	0	0	0	
Roll gyro high power	0	0	0	0	0	0	1	0	0	0	0	
Skew gyro high power	0	0	0	0	0	0	0	1	0	0	0	
Pitch resolved output	0	0	0	0	0	0	0	0	1	0	0	PD06
Yaw resolved output	0	0	0	0	0	0	0	0	0	1	0	PD07
Roll resolved output	0	0	0	0	0	0	0	0	0	0	1	PD08

(d) Pitch rate demands

Verify by noting change in telemetry volts CP04:

Description	D	E	F	G	H	I	J	K	Tele. volts change
Negative orbit rate	1	0	0	0	0	0	0	0	+3.0145V
Positive orbit rate	0	1	0	0	0	0	0	0	-3.0145V
±12 degrees/hour square wave (half-period 80min)	0	0	1	0	0	0	0	0	±0.166V
± 8 degrees/hour square wave (Half-period 16.6min)	0	0	0	1	0	0	0	0	±0.111V
+12 degrees/hour	0	0	0	0	1	0	0	0	-0.166V
-12 degrees/hour	0	0	0	0	0	1	0	0	+0.166V
+ 8 degrees/hour	0	0	0	0	0	0	1	0	-0.111V
- 8 degrees/hour	0	0	0	0	0	0	0	1	+0.111V
Zero rate	0	0	0	0	0	0	0	0	

Table A2 (concluded)

(e) Command: mode change

Description	D	E	F	G	H	I	Verification
Mode 3	0	0	0	0	0	0	CD30
Mode 2	1	0	0	0	0	0	CD30
Mode 4	0	1	0	0	0	0	CD30
Mode 5	0	0	1	0	0	0	CD30
Mode 9A	0	0	0	1	0	0	CD30
Mode 3A	0	0	0	0	1	0	CD30
Mode 6	0	0	0	0	0	1	CD30

(f) Command: gas jet exercise

Description	D	E	F	G	H	I	Verification
Pitch positive exercise	1	0	0	0	0	0	Examination of gyro output
Pitch negative exercise	0	1	0	0	0	0	
Yaw positive exercise	0	0	1	0	0	0	
Yaw negative exercise	0	0	0	1	0	0	
Roll positive exercise	0	0	0	0	1	0	
Roll negative exercise	0	0	0	0	0	1	

Table A3

Direct commands

No.	Title	Description/indication of operation
1	Override ACS stop	Overrides the ACS stop signal to the tape recorder. Indicated by bit DD56 (1 if ACS has been overriden).
2	High speed mode select	Enables high speed data stream. Inhibits data to the tape recorder. Routes high speed data to telemetry. Indicated by bit DD17 (0 if high speed mode is enabled).
3	Tele Tx 'A' select	Selects transmitter A and its pre-modulation filter. Indicated by bit DD51 being a '1'.
4	Tele Tx 'B' select	Selects transmitter B and its pre-modulation filter. Indicated by bit DD51 being a '0'.
5	Clock A select	Routes power to clock source A and removes power to clock source B. Indicated by DD31 being a '0'.
6	Clock B select	Routes power to clock source B and removes power to clock source A. Indicated by DD31 being a '1'.
7	Divider A1 select*	Routes power to first part of divider chain A and removes power from first part of divider chain B. Indicated by DD32 being a '0'.
8	Divider B1 select*	Routes power to first part of divider chain B and removes power from first part of divider chain A. Indicated by DD32 being a '1'.
9	Divider A2 select*	Routes power to second part of divider chain A and removes power from second part of divider chain B. Indicated by DD33 being a '0'.
10	Divider B2 select*	Routes power to second part of divider chain B and removes power from second part of divider chain A. Indicated by DD33 being a '1'.
11	ADC A select	Routes power to ADC A and removes power from ADC B. Indicated by DD34 being a '0'.

* Resets frame counter to zero.

Table A3 (continued)

No.	Title	Description/indication of operation
12	ADC B select	Routes power to ADC B and removes power from ADC A. Indicated by DD34 being a '1'.
13	Serial data stream A1 select	Routes power to part of the parallel to serial converter A and part of the serial digital multiplexer A and removes power from the equivalent parts of parallel to serial converter B and serial digital multiplexer B. Indicated by DD35 being a '0'.
14	Serial data stream A2 select	Routes power to part of the parallel to serial converter A and part of the serial digital multiplexer A and removes power from the equivalent parts of parallel to serial converter B and serial digital multiplexer B. Indicated by DD36 being a '0'.
15	Serial data stream B1 select	Routes power to part of the parallel to serial converter B and part of the serial digital multiplexer B and removes power from the equivalent part of parallel to serial converter A and serial digital multiplexer A. Indicated by DD35 being a '1'.
16	Serial data stream B2 select	Routes power to part of the parallel to serial converter B and part of the serial digital multiplexer B and removes power from the equivalent parts of parallel to serial converter A and serial digital multiplexer A. Indicated by DD36 being a '1'.
17	TR router A select*	Routes power to tape recorder and data routing control A and removes power from tape recorder and data routing control B. Indicated by DD38 being a '0'.
18	TR router B select*	Routes power to tape recorder and data routing control B and removes power from tape recorder and data routing control A. Indicated by DD38 being a '1'.

* Additionally it removes separation interlock, overrides ACS stop signal, overrides the 'override ACS stop' command, enables the playback timer, resets the mode to low speed, i.e. record and selects tape recorder A, track 1.

Table A3 (continued)

No.	Title	Description/indication of operation
19	TR A select	Selects tape recorder A and inhibits tape recorder B unless the separation interlock is present when tape recorder B is also selected. (It enables replay data from tape recorder A should playback be commanded and it also enables the selection of track to be recorded, on tape recorder A, if 'record' is commanded.) Indicated by DD22 being a '1' and DD23 being a '0'.
20	TR B select	Selects tape recorder B and inhibits tape recorder A unless the separation interlock is present when tape recorder A is also selected. (It enables replay data from tape recorder B should playback be commanded and it also enables the selection of track to be recorded, on tape recorder B, if 'record' is commanded.) Indicated by DD23 being a '1' and DD22 being a '0'.
21	TR record	Increments recording to the next track. Commands the selected tape recorder into the record mode. Resets clock to zero (data begins at frame 0 word 000). Resets the timer. Resets the tape recorder stop bi-stable. Inhibits the playback mode. Resets data rate to low speed. Cancels playback high speed mode and tape recorder stop bi-stables. Indicated by DD27 being a '1'.
22	TR playback	Commands the selected tape recorder into the playback mode. (Selection of TR playback when the separation interlock is present will replay both recorders simultaneously.) Resets data rate to low speed. Enables the playback timer. Cancels the tape recorder stop bi-stable. (The first TR playback command resets the separation interlock bi-stable if separation inter lock is no longer present. This ensures that only one tape recorder can be selected at a time from here on.) Routes playback data to the selected transmitter. Inhibits real time data to the transmitter. Inhibits data to the tape recorder. Indicated by DD28 being a '1'.
23	TR stop	Inhibits tape recorder drive and data. (Only effective in record mode because HS mode causes the recorder to run, but data is inhibited.) Indicated by DD24 being a '1'.
24	TR drive A select	Routes power to tape recorder drive A and removes power from tape recorder drive B. Indicated by DD37 being a '0'.

Table A3 (continued)

No.	Title	Description/indication of operation
25	TR drive B select	Routes power to tape recorder drive B and removes power from tape recorder drive A. Indicated by DD37 being a '1'.
26	Transmitter ON	Closes transmitter power switch relay thus supplying +12V to either transmitter. Indicated by the presence of an RF output at 137.44MHz from the spacecraft.
27	Transmitter OFF	Open transmitter power switch relay thus removing +12V from either transmitter. Indicated by the cessation of 137.44MHz signal from the spacecraft.
28	User switch 1 ON	Closes user switch 1, 4-pole latching relay, thus supplying +12V, -12V, +5V, -5V to experiment 'B'. Indicated by PD01 being a '1'.
29	User switch 1 OFF	Opens user switch 1, 4-pole latching relay, thus removing +12V, -12V, +5V, -5V from experiment 'B'. Indicated by PD01 being a '0'.
30	User switch 2 ON	Closes user switch 2, 4-pole latching relay, thus supplying +12V, -12V, +5V, -5V to experiment 'C'. Indicated by PD02 being a '1'.
31	User switch 2 OFF	Opens user switch 2, 4-pole latching relay, thus removing +12V, -12V, +5V, -5V from experiment 'C'. Indicated by PD02 being a '0'.
32	User switch 3 ON	Closes user switch 3, 4-pole latching relay, thus supplying +12V, -12V, +5V to experiment 'D'. Indicated by PD03 being a '1'.
33	User switch 3 OFF	Opens user switch 3, 4-pole latching relay, thus removing +12V, -12V, +5V from experiment 'D'. Indicated by PD03 being a '0'.
34	Battery trickle charge OFF	Opens charge control relay. This allows the battery to be charged at the high rate, provided the thermal logic will allow this, i.e. the high rate of charge is only possible if the battery temp. is below +35^{o}C. Indicated by PD04 being a '1'.

Table A3 (continued)

No.	Title	Description/indication of operation
35	Battery trickle charge ON	Closes charge control relay. This ensures that battery is charged at trickle charge rate only. Indicated by PD04 being a '0'.
36	Array deploy	Closes array deploy pyrotechnic relay driver providing the inhibit has been removed by successful separation from the 4th stage. (Successful deployment = DD57 and DD58 being 00)
37		Not allocated.
38	Command register 'A' select	Enables command register 'A' and inhibits command register 'B'. Only commands 40 and 42 can be used to fill the register which may only be executed by sending command 44.
39	Command register 'B' select	Enables command register 'B' and inhibits command register 'A'. Only commands 41 and 43 can be used to fill the register which may only be executed by sending command 45.
40	Logic level 0(A) select	Provides a logic 0 level to command register 'A' filling a MSB position and shifting all other bits in the register and one place to the right.
41	Logic level 0(B) select	Provides a logic 0 level to command register 'B' filling the MSB position and shifting all other bits in the register one place to the right.
42	Logic level 1(A) select	Provides a logic 1 level to command register 'A' filling the MSB position and shifting all other bits in the register one place to the right.
43	Logic level 1(B) select	Provides a logic 1 level to command register 'B', filling the MSB position and shifting all other bits in the register one place to the right.
44	Execute stored commands in register 'A'	Executes the command stored in register 'A' (WARNING: this command must NOT be sent until the contents of the register have been checked. This command may be repeated any number of times).
45	Execute stored commands in register 'B'	Executes the command stored in register 'B' (WARNING: this command must NOT be sent until the contents of the register have been checked. This command may be repeated any number of times).

Table A3 (continued)

No.	Title	Description/indication of operation
46	Mode 2 select	Selects the prime sun acquisition mode of the ACS using rate model and switching logic (part of experiment 'A'). Acquires using coarse sun sensors and gyros in rate mode. Indicated by CD38 being a '1'.
47	Mode 8 select	Selects the emergency sun acquisition (yaw/roll failure) mode of the ACS, using back-up loops incorporating simple level detector and monostable circuits, (does not use experiment 'A'). Acquires using coarse sun sensors and gyros in the rate mode. Indicated by CD34 being a '1'.
48	Mode 8A select	Select the emergency sun acquisition (pitch failure) mode of the ACS. Yaw/roll loops are as for mode 2 pitch loop is as for mode 8 except that the skew gyro is used in place of the pitch gyro.
49		Not allocated
50		Not allocated (station test command)
51		Not allocated
52		Not allocated
53		Not allocated
54		Not allocated
55		Not allocated
56		Not allocated
57	Gain change (7%) detector 3	Receipt of a single command pulse causes IR detector 3 amplifier gain to change by 7%. Two states are possible, viz normal or -7%. Normal gain is indicated by ED14 being a '1'; -7% gain, (-1 state), is indicated by ED14 being a '0'. (Actual gain of detector 3 amplifier depends upon the status of command 58 as well as 57.)
58	Gain change (14%) detector 3	Receipt of a single command pulse causes IR detector 3 amplifier gain to change by 14%. Two states are possible, viz normal or -14%. Normal gain is indicated by ED13 and/or ED16 being a '1'; -14% gain (-2 state) is indicated by ED13 and/or ED16 being a '0'.

Table A3 (continued)

No.	Title	Description/indication of operation
59	Gain change (7%) detector 4	Receipt of a single command pulse causes IR detector 4 amplifier gain to change by 7%. Two states are possible, viz normal or -7%. Normal gain is indicated by ED12 being a '1'; -7% gain, (-1 state), is indicated by ED12 being '0'. (Actual gain of detector 4 amplifier depends upon the status of command 61 as well as 59.)
60		Not allocated.
61	Gain change (14%) detector 4	Receipt of a single command pulse causes IR detector 4 amplifier gain to change by 14%. Two states are possible, viz normal or -14%. Normal gain is indicated by ED11 and/or ED15 being a '1'; -14% gain (-2 state) is indicated by ED11 and/or ED15 being a '0'.
62	Step mirror forward	Receipt of a single command pulse causes the canopus mirror to be stepped forward 1.5 degrees. Indicated by a change in bit pattern (bits ED01, ED02, ED03, ED04).
63	Step mirror backward	Receipt of a single command pulse causes the canopus mirror to be stepped backward 1.5 degrees. Indicated by a change in bit pattern (bits ED01, ED02, ED03, ED04).
64	Step threshold setting	Four threshold settings are available. They are nominally 25%, 50%, 100%, 200% of expected canopus signal. One, two or three commands are required to select a particular setting. Indicated by a change in bit pattern (bits ED05, ED06. Code - see Appendix B, Table B3.)
65	Override eclipse warning	Overrides eclipse warning signal to canopus sensor from IR4 detector. Receipt of a second command removes the override. Indicated by ED07: 1 = override, 0 = not overriden.
66	Calibrate canopus	Checks the calibration of the image dissector tube (by observation of ES06 star sensor magnitude). Receipt of a single command causes the scan mechanism to be offset to look at a beta light calibration source with one half of the image dissector and black space with the other half. Receipt of a second command returns scan mechanism to normal position. Indicated by ED08, 1 = calibrate, 0 = normal mode.

Table A3 (concluded)

No.	Title	Description/indication of operation
67	AS integration period 1ms	Selects 1ms integration period between samples. Indicated by ED21 in minor frame 0 being a '1' and ED22 and ED23 being '0'.
68	AS integration period 4ms	Selects 4ms integration period between samples. Indicated by ED22 in minor frame 0 being a '1' and ED21 and ED23 being '0'.
69	AS integration period 16ms	Selects 16ms integration period between samples. Indicated by ED23 in minor frame 0 being a '1' and ED21 and ED22 being '0'.
70		Not allocated.

Appendix B

USE OF NASA AND MOD FACILITIES

B.1 Operations

B.1.1 The battery fitted to Miranda was of marginal capacity to power the satellite from umbilical ejection just prior to launch until the satellite was within range of the Lasham ground station. Therefore, if after injection there was a malfunction during the automatic sequence to deploy the array and acquire the sun, the satellite might have insufficient power to respond to remedial commands from Lasham.

To minimise this risk it was decided to transmit the back-up array deploy command as soon after injection as possible.

The NASA telemetry and telecommand station at Tananarive, Madagascar was selected for the task because the satellite would be within range approximately 20min after injection.

An operations plan was devised by RAE for implementation by the NASA station. The plan consisted of two parts:-

(i) The routine sequence which included transmission of the array deploy command and replay of one satellite tape recorder to recover data pertaining to the launch, separation and sun acquisition phases.

(ii) The emergency sequence to be used if the station failed to acquire the satellite telemetry signal.

The complexity of operations for this seemingly simple task is of interest (see flowcharts in Figs.B1 and B2). The ground station is manually operated and the staff had no previous knowledge of Miranda apart from two simulations made before launch.

The precise operational requirements laid down for NASA for immediate post injection operations are given below.

B.1.1.1 Routine operations (Fig.B1)

(a) Receive the satellite carrier signal.

(b) Send the array deploy command.

This command is a back-up to an on-board automatic process which should have occurred by the time the satellite is in the Tananarive

reception range. This command will be sent without examination of the telemetry data.

(c) Send the direct data command. This command causes modulation of the carrier by direct data.

(d) At a pre-specified time, command one of the two on-board tape recorders to play back its tape. This play-back contains the launch and injection phase data and is of considerable importance to RAE.

(e) To receive and record on a video tape recorder, calibrated with station time, the modulated data (play back) at a bit rate of 2048 (split phase C code).

(f) At a pre-specified time to send a command to select record mode. In this mode the satellite sends unmodulated carrier only. On sending the record command the time of day should be noted. (This time is required with an accuracy of $\pm\frac{1}{4}$ second.)

(g) To inform the control centre at RAE of the progress of the pass and any anomalies that are noticed.

B.1.1.2 Emergency sequence (Fig.B2)

A contingency requirement if the satellite is radiating no carrier has been catered for by the emergency sequence. This situation could occur if the satellite transmitter that was selected before launch has failed. The emergency sequence would then be initiated after a pre-specified time interval from expected acquisition of carrier had elapsed. The time specified will take into account:-

(a) that the satellite might arrive late due to orbit injection errors,

(b) small inaccuracies for acquisition time in the prediction program.

B.1.1.3 The routine operations and emergency sequence are both presented in the form of flow charts (see Figs.B1 and B2) and a box by box description is given.

Two types of boxes are used in the flow charts:

(a) Diamond boxes which are TESTS and have one input and two possible exits; one exit if the result of the TEST is true and the other if false.

(b) Rectangular boxes are ACTIONS with one input and one exit.

B.1.2 <u>Routine operations flow chart description</u>

The purpose of this flow chart is to:-

(a) Acquire the satellite carrier.

(b) Command direct data.

(c) Send the array deploy command.

(d) Play back the satellite tape recorder.

(e) Command the tape recorder to its record mode.

For explanation of specified times see section B.1.5.

For command details see section B.1.4.

Explanation of boxes.

Box 1 Start.

Box 2 Does the time of day equal the specified earliest time (T_0) at which the satellite is expected?

Box 3 Is carrier signal being received?

Box 4 Has specified latest time (T_0 + N) for carrier acquisition been reached?

Box 5 Note time (T_1) when carrier was acquired (AOS time).

Box 6 Send command 36 to DEPLOY ARRAY using satellite decoder addresses A and B.

Box 7 Is it time (T_1 + M) for tape recorder PLAY BACK?

Box 8 Send command 22 to PLAY BACK tape recorder using decoder addresses A and B.

Box 9 Has 120 seconds elapsed? (Maximum time for data to appear.)

Box 10 Is carrier modulated?

Box 11 Wait a further 180 seconds to allow full tape play back (i.e. total of 260 seconds from successful action of play back command).

NB: May contain some periods of no modulation.

Box 12 Send command 21 to select tape recorder RECORD mode using decoder address A only.

Box 13	Is carrier unmodulated?
Box 14	Note time at which modulation ceased, i.e. when RECORD mode was initiated. Accuracy ±¼ second.
Box 15	Monitor for loss of signal (LOS) at end of pass.
Box 16	Note time of LOS.
Box 17	Inform RAE of LOS time, RECORD mode time, AOS time and other pass information.
Box 18	Send command 36 to DEPLOY ARRAY using decoder address A and B.
Box 19	Perform emergency sequence flow chart.
Box 20	Is carrier signal being received?
Box 21	Inform RAE NO CARRIER.
Box 22	Continue search for carrier.
Box 23	Has specified LOS time (T2) been reached?
Box 24	Note time when carrier was received.
Box 25	Inform RAE if carrier was not received.
Box 26	Send command 22 to PLAY BACK tape recorder using decoder address A and B.
Box 27	Has 120 seconds elapsed? (Maximum time for data to appear.)
Box 28	Is carrier modulated?
Box 29	Inform RAE tape recorder PLAY BACK command fail.
Box 30	Send command 21 to select tape recorder RECORD mode using decoder address B only.
Box 31	Is carrier modulated?
Box 32	Inform RAE, satellite is due in DIRECT DATA mode.
Box 33	END.
Box 50	Send command number 2 to obtain direct data mode using decoder addresses A and B.
Box 51	Check that bit sync. has been obtained.
Box 52	Check receivers are not tuned to a side band.

Box 53 Is second LSB of word 103 equal to '0'? (Confirms direct data mode.)

Box 54 Is second LSB of word 103 equal to '1'? (Confirms play back mode.)

Box 55 Is second LSB of word 103 equal to '1'? (Confirms play back mode.)

B.1.3 Emergency sequence flow chart description

This sequence is initiated when Box 18 has been completed.

The purpose of the flow chart is to switch on one of the two on-board telemetry transmitters.

Box 34 Send command 4 to select transmitter B using satellite decoder A.

Box 35 Send command 26 to switch selected transmitter ON using decoder address A.

Box 36 Wait five seconds.

Box 37 Has carrier been acquired?

Box 38 Send command 3 to select transmitter A using decoder address B.

Box 39 Send command 26 to switch selected transmitter ON using decoder address B.

Box 40 Wait five seconds.

Box 41 Has carrier been acquired?

Boxes 42 and 49 as Boxes 34 through 41 but using other satellite decoder address where appropriate.

B.1.4 Detailed command information

(i) Introduction

The spacecraft command system receives, and acts upon, 70 different tone digital commands conforming to NASA Aerospace Data Systems Standards, Part II, Section II.

Carrier frequency	148.25MHz
Sub carrier frequency	7.0KHz
Modulation	PDM/AM/AM

(ii) Satellite decoder address

Decoder	Octal
A	267
B	011

(iii) Commands

Command No.	Function	Execute word octal
2	Direct data select	027
3	TxA select	033
4	TxB select	035
21	Record mode	125
22	Play back mode	126
26	TX 'ON' select	143
36	Array deploy	207

NB: The numbering of the X4 satellite commands is arbitrary.

(iv) Details of commands to be sent

(a) Routine operation

Command 2 To select direct data mode. This can be checked by correct bit sync and will verify correct receiver tuning.

Command 36 To deploy solar array in case the on-board automatic sequence has failed. This command will be sent without reference to the state of the array. Sent twice using satellite decoder addresses A and B.

Command 22 To play back and record the launch sequence data stored on the satellite tape recorder. Sent twice using satellite decoder addresses A and B.

Command 21 To select RECORD mode of the on-board tape recorder after playback is complete - sent 280 seconds after start of PLAY BACK.

NB: Command 21 is sent ONCE ONLY using satellite decoder address A for Box 12 (see routine flow chart) or address B for Box 30.

(b) Emergency sequence

Command 4 To select satellite transmitter B.

Command 26 To switch on the selected transmitter.

Command 3 To select satellite transmitter A.

NB: These commands are only sent using one satellite decoder address as specified in the flow chart.

B.1.5 Specified times in the operations flow charts

Various times are specified in the operations flow charts at which phases are to be initiated. Most times are relative to t_1, the time at which the satellite carrier is received:-

('t_0') Expected AOS time

This is defined as the time at which the satellite is expected to be just 'visible' to Tananarive, i.e. time for acquisition of satellite (AOS). This time is based on predictions and assumes that the satellite is launched on time and goes into a nominal orbit. This time will have to be updated by Western test range (WTR) if there is a hold in the countdown.

('t_1') Actual time for AOS

This is defined as the time at which the satellite carrier was actually first received. This will be equal to 't_0' if the constraints for t_0 above are met. Most other time dependent events are referenced to 't_1'.

('t_0 + N') Time for emergency sequence

'N' is defined as the time in minutes at which, if the satellite carrier has not been received, the emergency sequence will be initiated. This period allows for small time errors in the prediction programme and also for late arrival due to a nominal orbit not being achieved. N has a value of $3\,{}^{+\frac{1}{2}}_{-0}$.

(t_1 + M) Time for initiation of tape recorder play back

M is defined as the time in minutes at which the play back command is to be sent to the satellite. [The time chosen will be such that play back should take place at the highest angles of elevation during the pass (for a nominal orbit)]. M has a value of 2.

(t_1 + M + 280) Time for record command

Two hundred and eighty seconds after receiving modulated data (play back) the command to select record mode will be sent.

't_2' Time for loss of satellite signal

This is defined as the time at which it is predicted (assuming nominal orbit, etc.) the satellite signal will be lost (LOS). Note: This time will have to be modified as 't_1' if the constraint for t_0 above is not met.

B.1.6 Notes on operations

(i) Tape recorders

There are two on-board tape recorders which, during the launch phases are both in operation. Both tape recorders will have been automatically stopped to conserve the launch data before the satellite is within the range of Tananarive. A dump command from Tananarive will cause a pre-determined tape recorder to replay its data.

(ii) Tape dump sequence

The replay period will be four minutes. Since the tape will be 'full' of data, modulated data ought to be received as soon as the command has been received. The replay data should cease a few seconds before an on-board four minute timer selects direct data mode. (This mode has the same format and bit rate as play back mode.)

(iii) Array deploy sequence

The array should automatically deploy before the satellite arrives within range of Madagascar, provided the following on-board criteria have been met:-

(a) a delayed separation signal is present, and

(b) the rates about all three axes are below a preset level.

The array deploy command from the ground is used as a back up and provides basically the o/p of the above AND function.

B.2 Tracking

B.2.1 NASA supplied orbital tracking data for 24 hours after launch.

B.2.2 MOD

Arrangements were made for MOD to supply tracking data from their various resources during the orbital life of Miranda. This information was transmitted over PO telex to the CC where it was input to a program that produced look angles and time predictions for each orbit in range of the ground station.

B.3 Communications

Arrangements were made before launch for the CC at RAE to be connected to the SCAMA (Satellite Conferencing and Monitoring Administration) telephone network and the NASCOM (NASA Communications) telex network via the London Switching Centre.

These links were used for operational messages before, during and immediately after launch between the CC and

(a) Launch site (WTR).

(b) NASA Langley.

(c) Goddard Space Flight Centre (GSFC).

(d) Tananarive (Madagascar).

(e) Johannesburg (used as back-up to Tananarive).

Appendix C

CONTROL CENTRE AND GROUND STATION

C.1 The Control Centre (CC) at RAE, in conjunction with the telemetry and telecommand station at Lasham, is used for controlling satellite operations.

Telemetry data, received at the Lasham station are sent in real time via an asynchronous modem link to the control centre for real time processing and data evaluation. Command instructions initiated at the Control Centre, either automatically or by operator are sent by a specially protected land line link to Lasham. The instruction sequence switches the command transmitter to radiate carrier and selects the appropriate control settings for the command encoder, the output of which modulates the carrier with the required tone digital format. Input and output messages to control the operations are typed on a silent teletypewriter (termed operations teletype in this Report) with a speed of 30 characters per second. Two visual display units (VDU), one for the controller and one for the use of experimenters, display selected satellite parameters and are updated twice during each pass. Thus two 'snapshots' of critical parameters are available and these can be useful in reassuring experimenters of the status of their experiments. Additionally, these units display diagnostic information on initiation by the satellite controller. A line printer, used in real time, can provide hard copy of diagnostic data for the satellite controller at his discretion. For post-pass work it provides hard copy of the results of 'quick look' analysis for the operations staff, experimenters and subsystem designers. Critical analogue data can be output to an eight channel hot wire recorder.

Lamp display panels provide the current status of satellite main subsystems and the configuration of the CC and Lasham equipment. These displays are updated during the pass.

A block diagram of both the CC and ground station is shown in Fig.C1.

C.2 The Lasham telemetry/telecommand station

The ground station associated with the CC is 20km distant and situated in a quiet electrical environment 200m above sea level. The height of the site gives excellent RF visibility enabling data to be received down to 1° elevation in any direction. Both reception of satellite telemetry and transmission of commands are carried out by the station.

C.2.1 Telemetry reception

The receiving station (see Fig.C2) operates in the 136-138MHz VHF band. The antenna is an array of crossed yagi elements of 23dB gain on an altazimuth mount with auto-follow control. Four receivers are operated in polarization diversity (vertical, horizontal, LH and RH (circular) and the strongest signal is automatically selected. The demodulated serial PCM signal from the receivers is reconstituted in a signal conditioner and relayed to the CC via asynchronous modems and PO lines. The serial data, both 'raw' and reconstituted, are recorded on magnetic tape together with an accurate time code, which is relayed from the CC. The signal chain from antenna to CC has complete redundancy. In addition, a lower gain antenna (16dB) and receiver system is available in case of catastrophic failure of the main telemetry station (see Fig.C3).

C.2.2 Telecommand transmission

The telecommands generated by the CC real time programs are relayed to the ground station via a special interface unit, modems and land lines. The telecommand facility (see Fig.C4) at Lasham has a more powerful transmitter and an antenna of greater gain than the command facility at RAE. It was mainly for this reason that the technique was developed to make the telecommand facility at Lasham a CC computer peripheral. The telecommand antenna can be slaved to the telemetry receiving antenna, thus eliminating the need for periodic updating of its position in azimuth and elevation during a satellite pass. Command signals modulate the ground transmitters for transmission to the satellite.

The telecommand antenna has a gain of 14dB in the range 148-150MHz. Three transmitters are available, two at 100W and one at 1kW. Commands may be generated in local control mode at the ground station by punched tape or by manual operation of a command encoder.

C.2.3 General

Status information indicating the correct functioning of ground station equipment are relayed to the CC where they are monitored by the pass operations program. Before each pass, a simulated satellite signal is radiated from a calibration tower at the ground station which enables a rapid functional check of all equipment from the receiving antenna through to the CC decommutation equipment. Similarly, the complete telecommand system from initiation by the CC to radiation of a modulated carrier by the ground transmitters can be verified

by initiating a test command, i.e. a command which would not be accepted by a satellite. A normal operating crew of two is necessary and it is in constant voice communication with the CC.

The station is equipped with diesel generators capable of supplying full load in the event of a mains power failure. Figs.C5 and C6 show views of the ground station and the control console respectively.

C.3 The satellite control centre

The control centre is situated in Space Department RAE (see Fig.C7). The basic function of the CC is to implement the satellite in-orbit control and experimental programme. This is achieved by receiving the satellite telemetry bit stream from the ground station and processing the data automatically in real time to determine the performance of the satellite. Based on this information, planned and/or corrective commands are generated and passed to the ground station for automatic transmission to the satellite. A further function of the CC is to carry out post pass analysis of the data in depth and to produce hard copy of specified parameters. The CC was fundamentally the same as it was for the in-orbit control of PROSPERO although additional facilities, including increased computer storage and faster input/output devices, were incorporated to meet the more complex operational requirements of MIRANDA.

C.3.1 Telemetry equipment

The incoming serial PCM bi-phase signal is input to the signal conditioner which establishes synchronism with the satellite bit rate and reconstitutes the bit stream into a noise free non-return to zero code (NRZ) output. This signal is passed to the frame synchroniser which detects the synchronising code in the serial bit stream and, using it as a reference, extracts the data syllables and transfers them in parallel to the telemetry data channel which is basically an interface device which carries out routing functions. From this, the syllables are input directly to the computer core store for analysis and for recording on digital tape.

For real time display, PCM data from the minor and major frame synchronisers are fed to the data distributor. This unit, by suitable patching, can extract up to 32 selected channels and, in conjunction with a digital to analogue (D to A) converter can drive either a hot wire or UV strip chart recorder. Both data distributor and D to A converter can also output any one of 32 selected channels each, to a 16 bit binary display. All essential items

of telemetry equipment can be set up (programmed) by the computer. Manual operation is also possible.

C.3.2 Computer and peripherals

The computer is an EMR 6130 machine with a core store of 32K 16 bit words and a memory cycle time of 775 nanoseconds. Two 16 megabit fixed discs and three IBM compatible tape machines constitute the backing stores. The disc stores are used for data manipulation and contain the real time and data processing programs. The magnetic tape machines are used for recording real time data and for production of master data tapes on which data processing is performed.

C.3.3 Input/output devices

Both real time and post pass control of the computer is exercised from a fast electronic teletypewriter with an electro-mechanical teletypewriter as a selectable back up. Real time and post pass program operator messages are input and output through this device. Selected output data from either the real time or post pass programs are routed to a line printer. Two visual display units are used in real time to display selected parameters. This information is to establish confidence in satellite performance and is used only exceptionally for diagnostic purposes in real time.

C.3.4 Analogue tape recorders and station clock

Two analogue tape recorders, one as back up, are used to record the incoming data from the ground station. This provides the ability to 're-run' the pass in the event of a failure associated with the computer or telemetry front end. An accurate (5 parts in 10^9 per day) station clock generates a time of day code for recording on the analogue tape and strip chart recorders and provides control times for the various real time and post pass programs. This unit also incorporates a tape search facility.

C.3.5 Ancillary equipment

Automatic control switching of some equipment, e.g. analogue hot wire strip chart recorders, is provided by a relay buffer unit controlled by the operations program. The back up command station, which is located on the roof of the CC building, is controlled from the CC and consists of the antenna positioning controls, command encoder, transmitters, command receiver and decoder. In the event of a computer malfunction commands can be sent manually.

A sophisticated PCM simulator and perturbation generator are available for use to establish correct functioning of telemetry equipment.

Two lamp displays, one situated in the CC, the other in the experimenters' room give an indication of critical satellite status. This lamp display is updated by program during the pass.

C.3.6 Communications

Transmission of telemetry, command data and voice to and from the ground station is achieved by high quality land line. Asynchronous modems are used for telemetry links and synchronous ones for command/status links. Commands to the ground station are sent via a special interface unit (known as the station link[3]) which also provides information relating to the status of the ground station for the operations program. This circuit includes a high level of error detection because of its operational importance.

C.3.7 Manning

The CC is manned for satellite passes and the running of post pass programs by a crew of three; satellite controller, teletype operator and back up command system operator.

C.3.8 Accommodation

The CC occupies an area of approximately 160 square metres. It is temperature and humidity controlled and maintained at class 100000 cleanliness. The area is divided into three rooms. The computer, discs and magnetic tape units are housed in one room. The operations room contains the telemetry, command and time code generator, together with the input/output devices and control console. The third, known as the experimenters' room, provides an area where experimenters, subsystem designers and VIPs can observe the operations in progress and the VDU and status display panel.

Appendix D

MIRANDA REAL TIME OPERATIONS

Although Miranda is no longer an operational satellite the real time operations described here are standard procedures which are still available. This Appendix is therefore written in the present tense throughout.

Fig.D1 shows a block diagram of the Miranda real time operations which consist of the following phases.

1 Set up.
2 AOS (acquisition of signal).
3 Data handling and power supply assessment.
4 ACS assessment 1.
5 ACS assessment 2.
6 ACS assessment 3.
7 ACS register update.
8 Experiment assessment.
9 Heat balance check.
10 Tape recorder replay.
11 Multiple commands.
12 Direct commands.
13 Record and LOS (loss of signal).
14 VDU (visual display unit).
15 Diagnostic routines,

D.1 Set-up phase

The set-up phase, details of which are entered on the pass schedule form (Fig.D2) for each pass, is initiated approximately half an hour before the start of a pass.

Its specific objectives are as follows:

(a) Establish communication between CC and ground station.

(b) Check for correct operation of telemetry and command systems (by using simulated data and test commands) at both the CC and ground station.

(c) Check telemetry and command data links.

(d) Automatically set up correct status of control centre equipment.

(e) Write header block to real time digital tape.

(f) Specify expected status of the ACS, data handling, power supplies and experiments of the satellite.

(g) Schedule replay of satellite tape recorder.

(h) Specify up to three multiple commands (two of which may be sent during replay), one of which may have a timed execute.

(j) Schedule direct command phase for planned direct commands.

(k) Specify special events, i.e. experiment switch-on or status change.

(m) Specify check of ACS register contents.

(n) Specify commands to reset ACS registers to preplanned patterns at end of pass.

(o) Specify pass control times for the following:

  (1) AOS time.
  (2) Emergency time.
  (3) Replay time.
  (4) Record time.

(p) Select either ground station or CC as command station and five or two word format.

(q) Set status lamps and count down clock.

Certain hardware such as the tape recorder, hot wire recorder and count down clock are automatically started when the pass starts by computer control of the relay buffer unit.

During the set up phase the option to display on the VDU (visual display unit) all registers containing parameter limits is offered. Additionally it is possible at this stage to change one or more limits, the effect of which is only operative for that pass.

Further details may be obtained from the pass schedule sheet (Fig.D2) and from the typical set-up phase print out (in Appendix E).

D.2 AOS phase (Fig.D14)

The AOS phase is initiated automatically at the completion of the set up phase. At the expected AOS time (input during set-up) the program waits for the signal 'Go' (carrier received) bit to be set (consistently for two seconds) by the ground station before sending the high speed data command. The signal

'Go' bit is automatically set when the carrier signal is approximately 8dB above ground receiver lock threshold to prevent the latter from losing lock when modulation is commanded effectively decreasing the carrier power by 6dB. Setting of this bit automatically starts the video tape recorder, hot wire analogue recorder and count-down clock and initiates transmission of the high speed data command. Minor frame lock is then monitored by examination of a flag bit from the frame synchronising hardware and must be faultless for five seconds before assessment of the satellite performance is begun.

Two automatic emergency phases may be initiated from the AOS phase. They are:

(a) Emergency phase A (no carrier).

(b) Emergency phase B (no modulation).

D.2.1 Emergency phase A (Fig.D15)

If no carrier received bit from the ground station is present by the prespecified emergency time which was input during the set up phase (approximately two minutes after expected AOS), the program outputs to the teletype the message "Is emergency time correct" to check for errors when the emergency time was input during the set up phase. If time is confirmed, the program automatically sends the array deploy command (first pass after launch only) and transmitter A select command. If this is successful the AOS phase is continued, if not transmitter B is commanded.

D.2.2 Emergency phase B (Figs.D16 and 17)

If the data are noisy or non-existent when high speed data mode is commanded, the program 'asks' whether Lasham has good data. If this is confirmed by the ground station the indications are that a line fault exists and back up lines may be selected. If, however, Lasham have poor or no data, an automatic sequence is begun to select transmitter A and then B and finally commanding all data handling redundancy circuits on board. The program returns to the AOS phase as soon as good data are received.

D.3 Data handling and power supply assessment (Figs.D18 to D23)

These phases check the status and performance of preselected parameters within the subsystems. The status is checked to match that expected, and in some cases automatic remedial action is taken to correct faults. Analogue parameters, i.e. voltages, currents, etc., are checked to lie between prescribed limits stored within the various programs. The phase is designed to give a

rapid indication of the working of the satellite but does not yield experimental data. The assessment is carried out in the following sequence.

D.3.1 Array deployment (first pass only)

Both the positive and negative array deployed status bits are checked and if one or both fail, the array deploy command is sent. The bits are then monitored continuously for 30 seconds and if both bits are not set within this time the raw array voltage and current parameters are output on the teletype to provide an indication of the degree of deployment.

D.3.2 ADC check

The identity of the operating ADC is verified to match with that which is expected and its positive, negative and zero calibrations checked between limits. Any failure of these limits is recorded and the redundant ADC is selected by command after the regulated power supply rails have been checked.

D.3.3 Regulated voltages

The ±12V and ±5V regulated voltage rails are checked between limits and if a fail occurs the relevant value is output to the teletype.

D.3.4 Experiments user switches

The states of the three user switches which control power to experiments are checked and compared with their expected states. A change of status of any one or more, is output on the teletype and the following action taken. If the IR or Albedo experiments have changed to 'on' the operator is given the option to command 'off'. In the case of the star sensor experiment, it is automatically commanded 'off'. In the event of any user switch having changed to 'off', the operator will be given the option to command the experiment 'on', which will occur automatically in the relevant experiment assessment phase.

D.3.5 Battery

The battery voltage is checked between limits. If the battery voltage is within limits the relevant charge rate is checked and, if main charge was previously selected, trickle charge is commanded. Failure of the charge limits results in their values being output on the teletype and the operator is given the option to initiate remedial action, i.e. to select the alternative charge rate. If the battery voltage is low, the value is output on the teletype, any user switches that are 'on' may be commanded 'off' to conserve power and main charge commanded, provided that battery temperature is below 35°C.

D.3.6 Power supplies (current and other voltages)

The following parameters are checked between limits.

+12V regulated output, current monitor.
-12V regulated output, current monitor.
+5V regulated output, current monitor.
-5V regulated output, current monitor.
+12V tape recorder supply, current monitor.
-12V tape recorder supply, current monitor.
+12V tape recorder supply, voltage monitor.
-12V tape recorder supply, voltage monitor.
Raw array bus voltage.
Raw array bus current.

Any failure of parameters will cause a message together with parameter value to be printed on the operations teletype.

D.3.7 Tape recorders

The selected tape recorder is identified and checked against expected status. If a change has occurred, a warning will be output to the operator so that the satellite controller is aware of possible problems during the replay phase and can plan his requirements in advance.

D.3.8 Data handling and transmitters

The states of the selected data handling units and transmitter are checked against their expected states and any change results in the new status being output to the operator. The option of commanding a change of status is given but no automatic action is taken.

A full print out of all parameters in assessment phases may be obtained by calling the relevant diagnostic routine.

D.4 Attitude control system assessment phase 1 (Figs.D24 to D34)

This phase occurs after the completion of the data handling and power supply checks. It is performed twice at this stage. The first assessment gives a print out of preselected parameters to the line printer and is available for experimenters' use. The second check outputs to the operations teletype the basic status of the ACS, advises of changes whereby remedial action can be taken and in critical situations automatically initiates remedial action. A block diagram showing the sequence of operational activities for changes in the expected mode, as an example, is shown in Fig.D92.

The following phases are directly associated with this check:-

(i) Set-up phase (Figs.D9 and D10).

(ii) Multiple command phase (Figs.D47 and D50).

(iii) Command verification phase (Figs.D51 to D54).

(iv) Actual verification phase (Fig.D55).

The main purpose of the assessment is to check the states of all spacecraft systems associated with the attitude control of the spacecraft. These are:-

(a) Mode status

(b) Sun sensor status

(c) Sun presence and gas jet failure routine (GJFR) status

(d) Gas jet status

(e) Gyro status

(f) Gas reducing valve pressure (medium and low)

(g) Gas tank pressure

(h) Register contents check

These checks are performed by storing the expected status into designated computer registers during the set-up phase. During the satellite pass, the actual status is stored into other designated computer registers. After suitable manipulation, the two registers which contain the corresponding status information, are compared. If the two registers are found to be equal then a message will be printed (on the respective output device) confirming 'STATUS OK' and followed, in the first assessment (output to line printer) by the actual status. If the registers are unequal, an output message 'STATUS CHANGED' followed by the exact nature of the change is printed on the respective output device.

D.4.1 Mode status

If the contents of the designated registers are equal a message 'MODE OK' is output on the operations teletype and the assessment continues to the next check.

If the contents differ then the message 'MODE CHANGED' is output to the operators teletype followed by a message indicating the new mode or reporting an invalid mode status. For most conditions the satellite will be returned to its expected mode by command. If however, mode 8A (emergency pitch acquisition) has been automatically selected additional checks and actions are performed by

the program. Mode 8A automatically selects the skew gyro to resolve the pitch axis but clearly it is undesirable to resolve a defective gyro in the yaw or roll axis, if the skew gyro was previously being used to maintain the satellite sun pointing. If this is the case, a message 'SKEW UNAVAILABLE' is output (the availability status being input during the set-up phase) and the program automatically commands Mode 8. In Mode 8 (emergency sun acquisition) the yaw and roll axes are controlled directly by the prime sun sensor and the roll and yaw gyros are not required.

Certain anomalies exist in the satellite functions which can give conflicting information. One such anomaly is encountered during this mode status check if the mode has changed to 8A. The normal gyro configuration of roll, yaw and pitch 'ON', skew 'OFF', changes when Mode 8A is entered to roll and yaw 'ON', pitch 'OFF', skew 'ON' and pitch resolved. However, the telemetered gyro status is not updated to indicate the new configuration. Therefore, when the program identifies a mode change to 8A *and* confirms from the skew gyro availability that 8A may be maintained, it automatically updates the telemetered gyro status by command.

D.4.2 Sun sensor status

The program checks that the selected sun sensor is as expected, and any status change is notified by output message to the teletype.

D.4.3 Sun presence and GJFR

The sun presence 'bits' for both the prime sun sensor (PSS) and fine sun sensor (FSS) together with their values in roll and yaw are output to the teletype. The GJFR is also checked here for convenience since its status is contained within the same telemetry word.

D.4.4 Gas jet and stop valve status

The program verifies that the selected status of the two stop valves and six gas jets are as expected and if so outputs to the teletype 'GJ STATUS UNCHANGED'.

If the status has changed the message is 'WARNING GJ STATUS CHANGED' and a further message reporting the new status is given. Automatic remedial action follows to command the jets and stop valves to their expected status unless either of the following states exist:

(a) the new status is prime stop valve closed redundant stop valve open and all redundant jets selected. This is because the GJFR has detected an excessive consumption of gas indicating a failure in one of the prime jets and automatically selected the redundant system. In this case no further action is taken but the expected status, stored in the program, is updated, or

(b) the program detects that one of the 'flags' which indicates a jet failure in one of the three axes is set. In this case the redundant system is automatically commanded and the expected status in the program updated.

D.4.5 Gyro status

The program verifies that the expected status of all four gyros is correct and outputs the message 'GYRO STATUS OK'. If the status has changed, the message is 'GYRO STATUS CHANGED' which is followed by a further message reporting the new status and showing whether any of the orthogonal gyros has been resolved by the skew gyro. The program then offers the satellite controller the option to change the gyro status. Note. Emergency Mode 8 may have been selected in which the roll and yaw gyros are not required.

D.4.6 Gas pressures

For this assessment the program outputs to the teletype the current values of gas pressure in the tank and at the first and second reduction valves.

D.4.7 Register contents check

The contents of each of the two on-board ACS command registers are examined if scheduled in the set-up phase. The expected pattern for each register is fed into the program during the set-up phase and a comparison is made with the actual contents.

If the expected and actual contents are the same, the operator is informed and is given the option (by typing 'Yes') to execute the command which is stored in the register. Both registers are examined in this manner if scheduled.

This option provides a useful facility whereby 'safe' commands previously sent and stored in the ACS command registers may be executed without the delay of loading these by command if an emergency situation occurs during high risk operations.

If the contents check indicates that a difference exists, the operator is informed and the pattern contained in the relevant ACS command register is printed out on the teletype. The operator is not given the option to execute

the command stored but is informed that the multiple command phase has been scheduled later in the pass during which the correct command pattern can be sent if required. (This command sequence would be fed in via the teletype.)

D.4.8 A full print out of all parameters may be obtained by calling the relevant diagnostic routine.

D.5 ACS assessment phase 2 (Fig.D46)

This phase is automatically scheduled for each pass and is similar to the ACS assessment phase 1 except that no line printer output is made. It is performed after the replay command, verify and execute phase (if scheduled) has been completed. Note. Multiple commands are usually sent to the satellite during the replay of satellite recorded data. In this way, the time taken to update the command registers is saved since it is being done whilst the recorded data are being received.

The prime object of this assessment is to check for any change in the ACS status that may have occurred since ACS phase 1. This second assessment may be up to six minutes later than the first one. It checks the status of the following:

Gas jets
Mode
Gyros
Sun sensors

D.5.1 Mode status

These checks are performed in a similar manner to those in ACS assessment phase 1, the main difference being that if the mode has changed from that expected, Mode 8 is selected rather than the expected mode (assumed not Mode 8 in this instance) since only a single command needs to be sent. Selection of the expected mode (Mode 3 for example) requires that an ACS register be selected (1 command), the correct pattern for Mode 3 sent (9 commands) and then after the register contents are checked, the command is executed (1 command). Since the satellite could at this time be at low elevation, the non-reception of a command or commands is a possibility. Therefore, the satellite is commanded into a safe operating mode (Mode 8) and remedial action can be made on the next pass.

If the mode has changed to 8A the program automatically updates the gyro status as in ACS phase 1. Since this is to update the status register, failure of this command is not critical.

D.5.2 Gyro status

Any change from the expected gyro status is automatically corrected by commanding the expected status.

D.5.3 Sun sensors

A check for sun presence of both the PSS and FSS are made. Absence of sun presence automatically initiates a command to Mode 8. Mode 8 operates directly from the PSS and another telemetry format anomaly exists here because the change in status from FSS selected to PSS selected that accompanies a change to Mode 8, is not reflected by a corresponding change in telemetered sensor status. To correct the telemetry status a PSS select command is transmitted, usually on the next pass because of time limitations.

D.6 ACS assessment phase 3 (Fig.D71)

This phase is provided for the remote possibility of an execute command corresponding in time exactly with an automatic decision in the ACS system to change either the state of the gas jets or the mode due to the diagnosis of the GJFR (automatic on-board system check) or at the loss of sun presence signal when one of two problems would occur:

(a) The gas jets selected would depend upon the contents of the command register actually being executed from the ground, or

(b) The mode entered, instead of being either Mode 8 or 8A (emergency mode), would depend upon the bit pattern being executed.

Although unlikely, a potential mission failure could occur if, for example, the gas jet status were selected with both stop valves closed. Therefore, this check, of the mode, gas jets and stop valves, is performed on every pass and as late in the pass as is practicable.

D.6.1 Mode status

Identical to ACS phase 2 except if the mode has changed to 8A, because of time limitations, the gyro status is not updated. A message is output to the teletype 'MODE NOW 8A - GYRO STATUS NOT UPDATED'.

D.6.2 Gas jets and stop valve status

Detection of a change in this status initiates automatic remedial action to select the expected status.

D.7 Update of ACS registers (Fig.D72)

This phase can be scheduled in the set-up phase. It allows specified command patterns to be set into the on-board ACS registers 'A' and/or 'B'. Neither of these commands is executed.

The purposes are four-fold:-

(a) It enables evaluation of the satellite reception of multiple commands to be made. (This is particularly useful early in life.)

(b) It enables the multiple commands to be sent up before the pass in which they are to be executed. This time saving could be important if a large number of commands had to be scheduled on a particular pass. The preceding pass could update the on-board registers with the first two commands for the following pass.

(c) If there is any evidence of, or concern about, the contents of either or both of the ACS registers being executed by spurious commands or by valid commands sent by a foreign agency, the filling of the registers with valid and safe patterns would ensure that even if executed, no change to the satellite ACS system would take place; e.g. in Mode 3, if both registers were filled with the correct pattern for Mode 3, then if executed by an external source (or due to some internal satellite problem), the current mode would be selected, thus causing no problem.

(d) It enables particular ACS commands to be always available for execution should this be necessary during a pass; e.g. Mode 3A pattern has regularly been updated into register A and prime jets select pattern into register B. During the pass, if selection of Mode 3A (safe back up of Mode 3) or selection of prime jets is required, this can be performed during the ACS contents check by typing 'YES' to the question 'Send execute?' Also, execution of one or both of these registers can be made at any time by interrupting the program and typing 'Go 5752' which reselects the ACS contents check phase. Note. A list of important box numbers is attached to the operations console for quick reference.

D.8 Experiments assessment phase

This phase assesses the performance of each experiment separately, performs scheduled commands and automatic remedial actions where possible to correct for malfunctions.

Each experiment assessment commences with a check of the relevant user switch status. If scheduled in the set-up phase, the experiment is automatically commanded 'on', providing there has been no power supply problem which has switched all the user switches 'off'. In this event, the operator is given the option to command the experiment 'on'.

Expected operating modes of each experiment are input and stored during the prepass set-up phase.

The assessment of each experiment continues as follows.

D.8.1 Albedo experiment (Fig.D39)

The integration period is checked to match that which is expected; any change is output to the teletype and automatic action initiated to command back to the expected status. If an invalid status appears, the 4ms integration period is automatically commanded.

Scheduled changes to the integration period are automatically commanded.

D.8.2 Infra-red experiment (Fig.D35)

The states of detectors 3 and 4 are checked to match with those expected and changes are output to the teletype and the option given to command back to the expected states. Scheduled gain changes are automatically commanded.

The assessment is completed by checking that the detectors, lens temperatures and chopper amplitude are between limits specified. Failure of any one of these three parameters causes the operations program automatically to command the experiment 'off'.

D.8.3 Star sensor experiment (Figs.D36 to D38)

If the experiment is to be switched 'on' during the pass, a Sanborne hot-wire recorder is employed to monitor the EHT value. After commanding 'on' there is a five second wait period to allow the EHT to stabilise.

Under experiment 'on' conditions the assessment continues as follows:

The EHT value is checked between limits and if a failure occurs the EHT is first checked for zero value which indicates that it has been switched 'off' due to glare present, and the operator informed. If glare is not present the value is output to the teletype and the option given to command the experiment 'off'. If Corona symptoms are apparent, rapid switch 'off' is available.

The assessment continues by checking whether the override eclipse warning (from the IR experiment) is set. If set, but scheduled as clear in the set-up phase, it is automatically inhibited by command.

The ON/OFF status of the calibration system is checked to match that expected, if incorrect or a change has been scheduled, the command is automatically sent.

The experiment calibration is exercised periodically by commanding it 'on' during the assessment phase and, providing no glare is present, commanding it 'off' during the LOS phase. If glare is present during the pass, and calibration 'on' has been scheduled, it will be left 'on'.

If scheduled, new mirror and threshold settings are commanded. The program outputs the current mirror position and threshold setting and the satellite controller specifies the number of commands necessary to attain the new settings. The commands are sent and the new position verified automatically.

When in Mode 5 and 5A (star lock), an assessment is made to determine whether star lock has been achieved. In this assessment the following two checks are performed automatically:

(i) Star lock trigger pulse is set, *and*

(ii) The rate about the pitch axis is nominally zero.

If both conditions are met, then the pitch axis has locked onto a star, and star lock assessment from replay data is automatically scheduled. If both the above conditions are not met, the program warns the operator that star lock has not been achieved and the satellite is automatically commanded into Mode 3 (inertial sun lock).

A full printout of all parameters may be obtained by calling the relevant diagnostic routine.

D.9 Heat balance assessment (Fig.D40)

This is the last check of the satellite performance assessment and consists of checking that the following temperatures lie within specified limits.

1 Yaw gyro
2 Structure +Y panel centre upper
3 Structure -Y panel centre lower
4 Solar array patch No.1
5 Solar array patch No.2

6	+Pitch jet
7	-Pitch jet
8	+Roll jet
9	-Roll jet
10	+Yaw jet
11	-Yaw jet
12	Tape recorder A
13	Tape recorder B
14	Tank No.5
15	Battery

A limit fail of any of these parameters results in the value being output to the teletype. No automatic remedial action is taken as a result of any out of limit parameters during this check.

A full printout of all the temperatures may be obtained by calling the relevant diagnostic routine.

D.10 Replay phase (Fig.D41)

During this phase, the data contained on the satellite tape recorder are transmitted to the ground station over the telemetry link. The initiation of this phase is time dependent, the time being specified in the set-up phase. When the start time has been reached, the replay command is automatically sent to the satellite. For the period of tape recorder replay, the program records data onto digital tape and waits for a consistent loss of data (10s) to indicate that replay has been completed. During replay, which lasts approximately 4min, the program will, if scheduled, carry out one of the following actions:-

(a) Send up to two previously defined multiple commands to register A and/or B without execution. (Explained in D.10.1.)

(b) Evaluate star sensor data if this phase has been scheduled from the star sensor assessment phase. (Explained in D.10.2.)

At the end of either of these options, a flag is checked which indicates whether the program waits for an automatic return to direct data (termed timer check) or to send the direct data command when replay has been completed. This flag is set in the set-up phase and normally the direct data command will be scheduled when cessation of replay data has been determined.

There are a number of contingencies associated with this phase:-

(1) The replay command is automatically resent using decoder 'B' if the first attempt fails.

(2) A software clock is started when the replay phase has been initiated. This clock is used to check that:-

(a) Reversion to direct data mode is not overdue if the timer check has been scheduled. The replay phase has a duration of $256 \begin{smallmatrix}-0\\+8\end{smallmatrix}$ seconds if the timer check has been scheduled.

(b) To indicate that the replay phase is due to be completed when in the star lock assessment phase.

(3) If the direct data command is not received, the onboard timer automatically selects direct data.

(4) If the timer check fails, the direct data command is sent.

D.10.1 <u>Commands sent during replay (Fig.D42)</u>

The following phases are directly associated with commands sent during replay:-

(a) 'Replay' commands pattern verify - (Fig.D45)

(b) 'Set-up phase' commands - (Fig.D12)

(c) 'Planned command' phase - (Figs.D47 and D48)

Also, in addition, for execution and satellite response tests the following figure numbers are relevant:-

(Figs.D49, D51 to D55).

<u>General</u>

This phase enables up to two of any of a total three planned commands, specified in the set up phase, to be sent during the reception of replay data. This feature is only allowed if star sensor evaluation has not been scheduled. The command or commands are automatically sent, the command pattern sent being taken from the appropriate planned command registers, i.e.

Command number 1 from register 20
Command number 2 from register 22.

The actual verification of correct reception of any commands sent cannot be made during replay and is performed immediately after the replay phase has been completed and direct data restored.

The 'replay' command pattern verify phase is only scheduled if at least one command has been sent. The pattern in the onboard ACS register 'A' is compared with the expected pattern. If this is the same, then the command is executed (delayed if a time dependent command) before assessing the contents of ACS register 'B', if a second command has been sent. If the first command was not properly received, the first command is automatically scheduled to be sent again in the planned command phase. If the second command is incorrectly received, then this too will be automatically resent during the planned command phase.

It is so arranged that even if three planned commands were scheduled in the pass (three is the maximum that the planned command phase has been designed to accept), with two being sent during replay, then all combinations of FAIL or PASS for the two 'replay' commands will be automatically catered for in the planned command phase.

D.10.2 Star lock assessment in replay (Fig.D43)

While the onboard tape recorder is being replayed, this program will be called and run if it has been automatically scheduled during the star sensor experiment assessment phase. This phase will only be scheduled if the Mode is 5 or 5A and there is an indication that a star lock about the pitch axis has been achieved.

The program checks for the first occurrence of the star presence signal in the replayed data and stores the value of the frame counter from the minor frame containing this information. The star lock trigger pulse is then searched for and when found, the minor frame counter in which it was first set is printed out on the TTY. The program then searches for the loss of star presence and again notes the relevant minor frame counter value. A value of the total number of minor frames during which the star presence signal was set is output on the TTY in decimal.

NOTE: Overflow of the 12 bit frame counter is taken into account. Various warning messages are printed out if necessary:

(a) 'NO STAR LOCK TRIGGER PULSE FOUND'.

(b) 'PROBABLY NOT LOCKED TO CORRECT STAR' if counter value is outside limits and trigger pulse is set.

(c) If the duration of presence is below a pre-specified number of minor frames (usually set at 30), the program automatically warns the operator and schedules Mode 3 (inertial sun lock) to be initiated immediately after the replay phase has been completed. This command sequence and verification of correct operation is automatic and calls for no input from the operator.

NOTE: The number of minor frames for which presence is 'found' is compared to a previously agreed number which is stored in a register. If a temporary change is required to this duration, this can be performed in the set-up phase. A permanent change requires a re-compilation of the program. At the end of the assessment, the program routes to replay phase timer check.

D.11 Multiple commands - general

Multiple commands can be initiated from the following phases:-

(a) Planned command (up to three, one of which may have a timed execute).

(b) TTY command (each may have a timed execute).

(c) Replay. (Up to two of those specified as planned commands.)

(d) ACS assessment (as remedial action).

(e) ACS register update.

The system block diagram (Fig.D92) showing the manner in which multiple commands are sent is described below.

The multiple command phase (sequence start point) is called from the phase from which the multiple command is initiated, e.g. planned command phase. The command pattern is stored in register number 1 and the number of bits to be sent is stored in register number 2. The action is as follows:-

(a) Decoder 'A' is scheduled for the command sequence.

(b) Register 'A' is selected by command.

(c) The command pattern (the correct number of bits only) is sent, least significant bit first.

(d) The contents of the onboard register 'A' is then compared with the actual pattern sent and, if correctly received, the 'time dependence check' program is entered. If the execute command is to be sent at a specific time, there will be a pause until that time has been reached.

The program then is routed to the execute phase where register 'A' execute command is sent twice; first with decoder 'A', then with decoder 'B'.

The program is then routed to the 'determination of command execute verification' program. This program examines the three most significant bits of the pattern sent (address bits) and calls the relevant 'satellite response to command' program. The appropriate satellite data are obtained and stored in a register and the program routes back to the 'actual command verify' program. The satellite response to the execute command is then compared with the response expected and if verification is received the program reverts back to the point from which the multiple command program was called. If there is no verification of correct execution, the execute command is automatically resent.

In the command pattern sending phase, if the command pattern is not received, the pattern is automatically sent using register 'B' and decoder 'B'. If this should also fail, the operator is informed that both attempts have failed and the contents of both registers are printed onto the operations teletype. The operator has the option at this point of changing command stations (and command aerial polarity, if necessary) before the program continues to update the register with the required pattern.

The pattern sending sequence for continuous failure of the command is:-

(a) Register 'A' decoder 'A'.

(b) Register 'B' decoder 'B'.

(c) Warning message and register contents output.

(d) Register 'B' decoder 'A'.

(e) Register 'A' decoder 'B'.

(f) Warning message and register contents and option to repeat through teletype.

D.11.1 <u>Planned multiple command phase (Figs.D47 to D55)</u>

This phase is the prime command sending phase. Up to three previously specified multiple commands can be automatically sent, one of which can be specified as having a time dependent execute, i.e. the command is executed at a pre-determined time.

The commands to be sent during this phase and the execute time, if relevant, are specified in the set-up phase.

The command pattern associated with command number 1 is stored in register 20 with the relevant number of bits in register 21. The command pattern associated with command number 2 is stored in register 22 with the relevant number of bits in register 23. The command associated with command number 3 is stored in register number 24 with the relevant number of bits in register 25. When one of the preplanned commands is to be sent, the contents of the register containing the actual command pattern is copied to register number 1 and the relevant number of bits to register number 2. The multiple command phase (common to all multiple commands) will then be called. When verification has been completed, the program returns to the planned command phase and sends the next command if a further command has been specified.

D.11.2 Teletype initiated multiple command phase

This phase is normally only used if more than three multiple commands are required to be sent during a pass. The program instructs the operator to type in through the operations teletype, the command pattern in octal in the form '*ABCDEF' and the number of bits to be sent in decimal. The command pattern is stored in register number 1 and the number of bits in register number 2. The command pattern and associated number of bits are then typed back on the teletype for the operator to confirm that the correct information has been given. If confirmation is given, the operator has the option to make the execute of that command time dependent. If this is required, the operator is requested to type in the time at which the execute command is to be sent. The program then calls the multiple command phase, and the command is sent, verified and executed. The operator is 'asked' if a further multiple command is to be sent. If 'YES' is typed, the process is repeated. If 'NO' is typed, the next phase is entered.

D.12 Direct commands phase (Figs.D56 to D70)

The direct commands phase is a self-contained series of flow-charts for the transmission and verification of direct commands with the exception of the commands which are actioned in the multiple command phases (commands 38 to 43 inclusive).

A direct command may be initiated either from a specific assessment phase automatically or from the teletype by typing GO followed by the command number required. If called from the teletype, the actual command function in English is printed out and the operator is asked to confirm the command entered before the program proceeds. Each command is sent and verified automatically. The verification is accomplished by using a common flow chart for those commands

that have a specific status bit within the telemetry format. Specific flow-charts, special to each command, are used for those that have no status bit or if the command is of the toggle action type.

If the satellite fails to respond correctly to a command, it is automatically repeated using the redundant decoder address. Subsequent failure presents the option to repeat and if desired to use the alternative command station.

D.13 Record and LOS phase (Fig.D76)

This is the last active phase of a pass. Included at the beginning of this phase are any scheduled star sensor calibration ON/OFF commands.

When the scheduled record time is reached the record phase commences by sending the tape recorder change command, if scheduled, followed by the requisite number of record commands to select the scheduled track. The time of the final record command is noted as a reference for subsequent analysis of recorded data and is input to the header block of the digital tape of the next pass. In order to reduce ambiguity as to which of the three execute commands was actually received, a two word command format is used (i.e. one address and one execute). In this way, accurate timing of the initiation of record mode can be established.

LOS (loss of signal)

This is the final phase of the pass, commencing when the last record command has been sent and culminating in the loss of the carrier received status bit from the ground station at which time the video tape recorder and hot wire recorders are automatically switched off.

D.14 Visual display unit (Figs.D73 to D75)

The VDU (visual display unit) takes the form of an alpha-numeric display presented on a CRT. Two parallel units are employed, one in the control centre and one in the experimenters' room.

During a pass each VDU will present a 'snapshot' showing real time data relating to the satellite performance, status and experiments primarily provided to reassure experimenters and subsystem designers. The information is available at the completion of the satellite performance assessment phase and is updated at the completion of the command phase. The amount of information that can be displayed on the VDU is limited and only the essential parameters indicating correct operation of each subsystem and experiment can be provided.

No attempt has been made to present engineering values and all analogue values and some digital data are output in octal. Octal numbers are indicated by the (*) prefix. A typical VDU output is shown below.

VDU OUTPUT NO 1 TIME 13 H 30 M 54 S

DATA HANDLING STATUS

T/R=A, TX=A RED=*0, ADC CAL=Z*200 P*100 N*370

POWER SUPPLY STATUS

*12V=*37, -12V=*343, +5V=*36, -5V=*342, +12TR=*37

-12TR=*342 RABV=*27, BATV=*33 T/CHG, U/SW=*7

EXPTS STATUS

ALBEDO ON =*2776, S/C V1=*200, S/C V2=*327

CAN ON, EHT=*230, MIR=*3, TH=*2, OEW=CLR, CAL=OFF

IR ON, DET3=*2, DET4=*2

ACS STATUS

G/STAT=*210, GJET=*100 PSS SEL, MODE=*40

PSS PRES, O/P YAW=*326, ROLL=*175

FSS PRES, O/P YAW=*200, ROLL=*177

PRES TANK=*136, RV1=*130, RV2=*55

TEMPERATURES

IR LENS=*214, DET=*213, CAN=*23

+PJET=*33, -PJET=*31, +YJET=*25, -RJET=*21

TANK=*102, T/R B=*66, BATT=*44, PGYRO=*75

S/C EXPT, P1=*250, P2=*240, STO2=*77, STO6=*26

D.15 Diagnostic routines (Figs.D78 to D86)

Five diagnostic routines are provided as follows:-

(a) Experiments (15.1)
(b) Heat balance (15.2)
(c) Power supply (15.3)
(d) Data handling (15.4)
(e) ACS No.1 (15.5)
(f) ACS No.2 (15.6)

These routines, each of which may be called up in real time, will display all relevant parameters on the VDU and provide a line printer output. They do not feature in the routine operational programs but are provided to assist during the diagnosis of a fault or malfunction that may occur, or to provide spot values of parameters. The data handling routine includes a tape moving and an AGC check, both of which can be called separately. Because of display limitations the ACS routine is divided into two parts.

No attempt has been made to present engineering values. All analogue and some digital data are output in octal. Octal numbers are identified by the (*) prefix. Typical examples of each diagnostic routine appear below.

D.15.1 Experiments diagnostic

INFRA-RED
STATUS= ON, DET/3=*2, DET/4=*2, ECLIPS WARN=CLEAR
PERFORMANCE
DET/1=*170, DET 1-2=*235, DET/2=*207, DET/3=*214
DET/4=*256, DET 3-4=*305
CHOPPER AMP =*131, TENS TEMP=*214, DET TEMP=*213
STAR SENSOR
STATUS= ON, MIR=*3, TH SET=*2, DEW=CLEAR, CAL=OFF
PERFORMANCE, STAR PRES=TRUE, STAR LOCK=TRUE
MAGTUD=*36, NULLING=*143, EHT=*230, TEMP=*23
ALBEDO
STATUS= ON, HK=*4776, TEMP=*25
DIODE O/P AS FOLLOWS A1 THROUGH A100
1-4 =*0, 5-12=*0, 13-20=*0, 21-28=*0
29-36=*0, 37-44=*177, 45-52=*377, 53-60=*377
61-68=*377, 69-76=*377, 77-84=*377, 85-92=*377
93-100=*377
PATCH 1V=*200, TEMP=*250, SOLAR CELL PATCH 2V=*327, TEMP=*240

D.15.2 Heat balance diagnostic

THERM REF=*73
POWER AND DATA SYSTEMS
T/R A=*31, T/R B=*66, PRDU=*35, PCU=*33
STRUCTURE
ST01=*104, ST02=*77, ST03=*36, ST04=*27
ST05=*65, ST06=*26, ST07=*23, ST08=*46

ACS

R GYRO=*72, Y GYRO=*74, P GYRO=*75, S GYRO=*75

FSS=*106, PSS=*132, ACEU=*50, HORZ D=*63

TANK 1=*112, TANK 2=*112, TANK 3=*111, TANK 4=*113

TANK 5=*110, TANK 6=*106, TANK 7=*105, TANK 8=*102

TANK 9=*112, TANK 10=*102

GJET+P=*33, GJET-P=*31, GJET+Y=*25, GJET-Y=*27

GJET+R=*102, GJET-R=*21

EXPTS

IR DET=*213, IR LEN=*214, STAR SENSOR=*23

ALBEDO=*25, S/C P1=*250, S/C P2=*240

D.15.3 Power supply diagnostic

STATUS

U/SW=*7, BAT CH=TRICKLE, TH RLY=CLOSED

TEMPERATURES

BATT=*44, PRDU=*35, PCU=*33, ARRAY=*33

VOLTAGES

+12V=*37, -12V=*343, +5V=*36, -5V=*342

+12VTR=*37, -12VTR=*342

BATT V=*33, RAB V=*27

CURRENT

+12I=*164, -12I=*205, +5I=*133, -5I=*210

+12ITR=*175, -12ITR=*145

BATT I=*177, RAB I=*141

D.15.4 Data handling diagnostic

TAPE RECORDER

B SELECTED, TRACK=3, STOPPED, PRES=*141, TEMP=*31

A PRES=*140, TEMP=*66

TRANSMITTER

A SELECTED POWER O/P=*140

STATUS

REDUNDANCY=*20, USER SWS=*7

ADC

B SELECTED, COM ZERO CAL=*200, POS=*100, NEG=*367

A POS=*100, NEG=*367

RECEIVERS

AGC A=*200

AGC B=*200

ACS O/RIDE-CLEAR

D.15.5 ACS diagnostic No.1

SENSORS

PSS=SEL, PRESENCE, O/P ROLL=*175, YAW=*326, TEMP=*132

FSS, PRESENCE, O/P ROLL=*177, YAW=*200, TEMP=*106

STAR LOCK-NONE, STAR PRES, =NONE

GAS SYSTEM

STATUS=*300, GJFR=ENABLED, AXIS FAIL=NONE

GYROS

ROLL=ON, O/P=*203, TORQ=*201, TEMP=*72

YAW=ON, O/P=*132, TORQ=*202, TEMP=*70

PITCH=ON, O/P=*200, TORQ=*200, TEMP2*71

SKEW=ON, O/P=*200, TEMP=*75

MODE=*000

D.15.6 ACS diagnostic No.2

SENSORS

SEC SS O/P ROLL=*200, YAW=*200

HORZ DET 1-NO PRES, TEMP+*50

HORZ DET 2-NO PRES

INTEGRATORS

PITCH=-*7777

YAW =-*3777

ROLL =-*3777

MODEL ESTIMATES

PITCH, RATE=*202, POSITION=*200, DIST TORQ=*177

YAW, RATE=*166, POSITION=*200, DIST TORQ=*177

ROLL, RATE=*206, POSITION =*200, DIST TORQ=*177

TEMPERATURES	PRESSURES
JET+P=*64, TANK 1=*127, TANK 7=*122	TANK=*135
JET-P=*74, TANK 2=*126, TANK 8=*120	RV 1=*130
JET+R=*103, TANK 3=*125, TANK 9=*126	RV 2=*55
JET-R=*21, TANK 4=*125, TANK 10=*121	
JET+Y=*25, TANK 5=*123, ACEU =*54	
JET-Y=*27, TANK 6=*121	

Appendix E

TELETYPE RECORD OF TYPICAL MIRANDA PASS

E.1 General

The following is a typical output from the operations teletype produced during one pass sequence. It includes the pre-pass set-up phase and post-pass program instructions.

It is the actual pass to which the schedule (Appendix D, Fig.D2) refers.

Explanatory notes

(1) All lines prefixed by letter I are replies input by the operator in response to questions output by the program.

(2) During this particular pass, two multiple commands, +1.6 deg/HR (*000332 -16 bits) pitch integrator and zero deg/HR (*060000 - 11 bits) prime rate about the pitch axis, were sent to the ACS registers A and B respectively. The registers were filled by commands during the satellite tape recorder replay and checked, executed and verified after replay.

(3) One direct command, battery main charge select, was sent in the direct command phase.

(4) The first section shows the pre-pass set-up phase where the satellite expected status, scheduled commands and control times for AOS, tape replay and record time are input to the program.

(5) The second section shows the actual pass data output to the teletype from AOS to LOS.

(6) The final section contains the post-pass program requirements being input to the computer.

(7) Reference to Fig.D1 will be of advantage in understanding the TTY print out, particularly for E3.

E.2 Teletype input/output data for E2 pass on day 140

SET-UP PHASE

```
X4 OPERATIONS
  DAY 140
  ORBIT NUMBER
I 1034
  DUTY SHIFT
I 28 EARA
  18 H 26 M 21 S
  CONFIRM LASHAM STATUS IS GO
```

I YES
CONFIRM CONTROL CENTRE STATUS IS GO

I YES
SIMULATION OK?

I YES
COMMAND TESTS

INST LHAM TO SEND TEST CMD M

COMMAND OK?

I YES
SEND TEST CMD M FROM C.C

COMMAND OK?

I YES
AUTO CMD REQD?

I YES
LASHAM TEST A

CONFRM READY

I YES
COMMAND OK?

I YES
COMMAND OK?

I YES
LASHAM OK

C.C. TEST A

COMMAND OK?

I YES
COMMAND OK?

I YES

C.C. OK

CFM DIG TAPE IS LOADED AND NO 1 IS SET TO LOAD POINT AND AUTO

I YES
HEADER

TYPE ORBIT NO

XXXX

I 1034
1034

OK?

I YES
TYPE PASS NO

XX

I E2
E2

OK?

```
I YES
  TYPE AOS TIME

  XX XX XX

I 18 39 00
  18 39 00

  OK?

I YES
  TYPE DAY NO FOR RECORD TIME

  XXX

I 140
  140

  OK?

I YES
  TYPE RECORD TIME FOR LAST PASS

  XX XX XX.XXX

I 17 11 36.006
  17 11 36.006

  OK?

I YES

  TYPE VIDEO TAPE NO

  XXX

I 074
  074

  OK?

I YES
  LIMITS PRINTOUT REQD?

I NO
  LIMIT CHANGE REQD?

I NO
  TAPE DUMP THIS PASS?

I YES
  TYPE RPLY TIME

I 18H42MOOS
  DATA HANDLING

  ADC A EXPTD?

I NO
  TYPE EXPTD USER SW STATUS

I *7
  *7 OK?

I YES
  T/R A EXPECTED?

I YES
  TYPE IN EXPECTED TRACK NO.
```

I 3
3 OK?

I YES
T/R A REQUIRED NEXT PASS?

I YES
HOW MANY RECORD CMDS REQD?

I 1
1 OK?

I YES
TX A EXPECTED?

I YES
TYPE IN REDUNDANCY STATUS IN FORM *ABC

I *033
*33 OK?

I YES
A.C.S. STATUS

TYPE IN MODE STATUS WORD 1

I *000
MODE 3?

I YES
TYPE IN GAS JET STATUS WORD 2

I *100
R S.V. CLOSED

P S.V. OPEN

- YAW PRIME

+ YAW PRIME

- PITCH PRIME

+ PITCH PRIME

- ROLL PRIME

+ ROLL PRIME

STATUS OK?

I YES
TYPE IN GYRO STATUS WORD 3

I *210
GJFR ENABLED

STATUS OK?

I YES
FSS SELECTED?

I YES
SET ACS REGS AT END OF PASS?

I YES
REGISTER A?

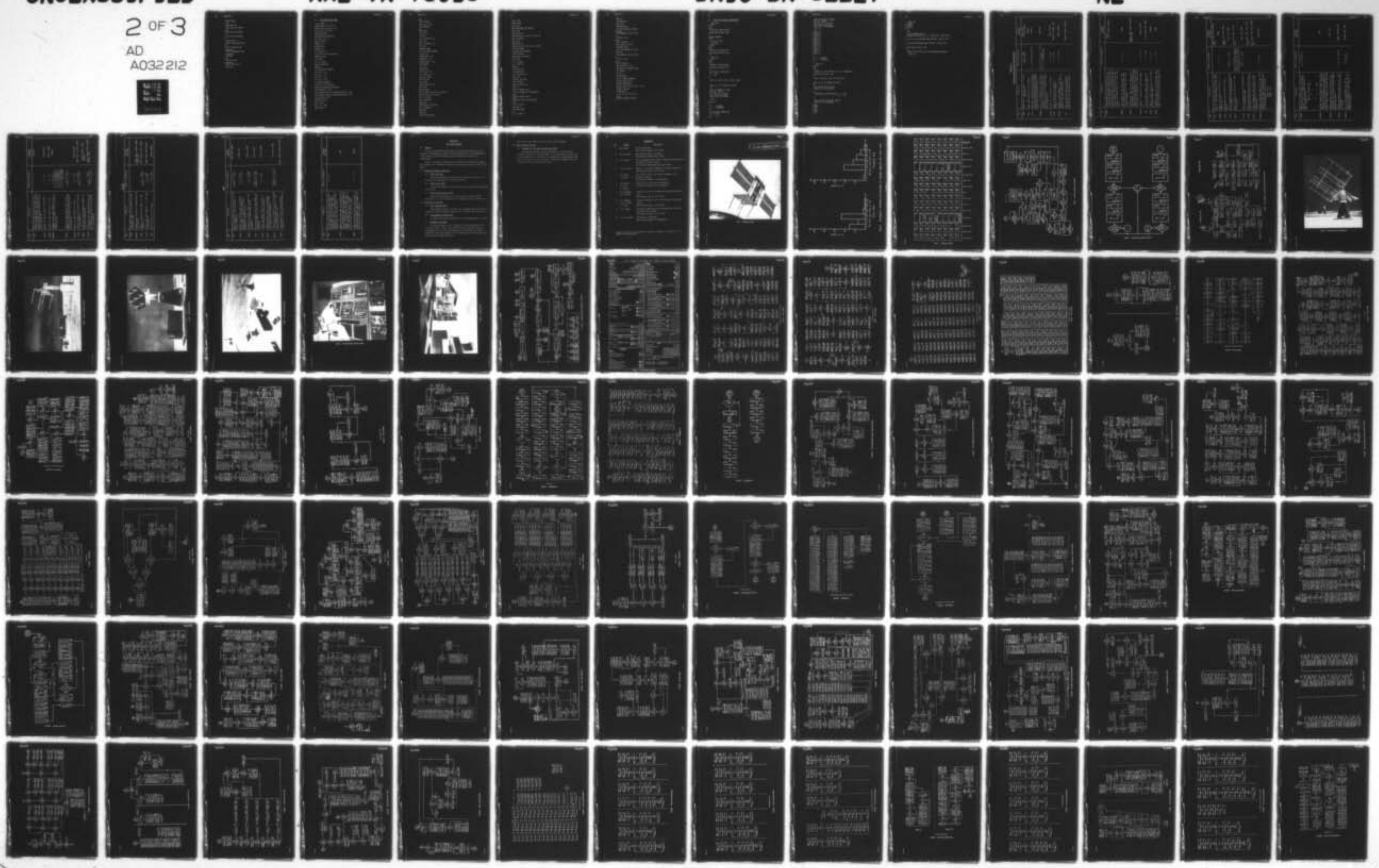
I YES
REGISTER B?

```
I YES
  ACS REGISTER CONTENTS CHECK REQUIRED?
I YES
  REGISTER A?
I YES
  TYPE IN OCTAL EXPECTED REGISTER A SETTING
I *100400
  TYPE NUMBER OF BITS IN DEC
I 9
  *100400 9 OK?
I YES
  REGISTER B?
I YES
  TYPE IN OCTAL EXPECTED REGISTER B SETTING
I *037740
  TYPE NUMBER OF BITS IN DEC
I 11
  *37740 11 OK?
I YES
  ALBEDO EXPT.
  TYPE IN EXPECTED OR NEW INTEGRATION PERIOD
I *1
  *1 OK?
I YES
  NEW THIS PASS?
I NO
  I.R. EXPT
  TYPE IN EXPECTED OR NEW DETECTOR 3 SETTING
I *2
  *2 OK?
I YES
  NEW THIS PASS?
I NO
  TYPE IN EXPECTED OR NEW DETECTOR 4 SETTING
I *2
  *2 OK?
I YES
  NEW THIS PASS?
I NO
  CANOPUS EXPT
  IS O.E.W. SET?
I NO
  CAL TO BE ON THIS PASS?
I NO
  TYPE IN EXPECTED MIRROR POS
```

```
I *6
  *6 OK?
I YES
  TYPE IN EXPECTED THRESHOLD
I *3
  *3 OK?
I YES
  MIRROR POSITION CHANGE?
I NO
  THRESHOLD CHANGE?
I NO
  CMD SET UP
  LASHAM FOR COMMAND SENDING?
I YES
  5 FORMAT CMD?
I YES
  ANY CMDS REQD?
I YES
  MULTIPLE CMDS?
I YES
  TYPE CMD PATTERN IN OCTAL
I *000332
  TYPE NUM OF BITS IN DECIMAL
I 16
  *332 16 OK?
I YES
  IS CMD TIME DEPENDENT?
I NO
  ANY MORE MULTIPLE COMMANDS?
I YES
  TYPE CMD PATTERN IN OCTAL
I *060000
  TYPE NUM OF BITS IN DECIMAL
I 11
  *60000 11 OK?
I YES
  IS CMD TIME DEPENDENT?
I NO
  ANY MORE MULTIPLE COMMANDS?
I NO
  ANY COMMANDS IN REPLAY?
I YES
   MORE THAN ONE?
I YES
```

AD-A032 212 ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) F/G 22/2
REAL TIME OPERATIONAL CONTROL OF MIRANDA.(U)
FEB 76 E A ANSTEY, M J HAMMOND
UNCLASSIFIED RAE-TR-76016 DRIC-BR-52227 NL

2 OF 3
AD
A032212



```
  DIRECT CMDS?

I YES
  PASS DURATION

  CLOCK AND R.B. READY?

I YES
  TYPE TENS OF MINUTES

I 1
  TYPE UNITS OF MINUTES

I 5
  CLOCK SET UP

  REPLAY TIMER CHECK REQ?

I NO
  TYPE IN RECORD TIME

I 18H52M30S
  TYPE IN EMERGENCY TIME

I 18H42M00S
  SIM OFF?

I YES
  TYPE AOS TIME

I 18H38M00S
  STATUS LAMP SET UP

  SAVE 1501
```

E.3 PASS OPERATIONS PHASE

A.O.S. PHASE

CARRIER RXD 18 H 39 M 5 S

DIRECT DATA 18 H 39 M 12 S

AOS AT 18 H 39 M 19 S

ADC EVALUATION

POWER SUPPLY EVALUATION

ADC AND P.S OK

USER SW CHECK

STATUS OK

BATTERY EVAL

BATTERY O.K

D/H STATUS O K

T/R SELECT OK AND ON TRACK 3

CORRECT TRACK

SAVE 2026

A.C.S. ASSESS.

MODE AS EXPECTED

REMAINS 3

PSS PRESENT FSS PRESENT

FSS YAW = *210

FSS ROLL = *173

PSS YAW = *170

PSS ROLL = *200

GJ STATUS UNCHANGED

GYRO STATUS AS EXPECTED

RESOLUTION REMAINS ORTHOGONAL

TANK PRESSURE = *136

GAS PRESSURE AFTER 1ST REDUCTION VALVE = *24

GAS PRESSURE AFTER 2ND REDUCTION VALVE = *37

STATUS LAMP SET UP

REGISTER CHECK

REG A CHECK

REG A OK = *402

SEND EXECUTE?

```
I NO
  REG B CHECK
  REG B OK = *777
  SEND EXECUTE?
I NO
  END PHASE
  SAVE 2526
  IR EVAL
  DET 4 SETTING = *2
  DET 4 OK
  DET 3 SETTING = *2
  DET 3 OK
  CANOPUS CHECK
  EHT OFF GLARE PRESENT
  CAL OFF OK
  MIRROR POSN = *6
  THRESHOLD = *3
  PACKAGE TEMP = *27
  END CANOPUS
  SAVE 2837
  ALBEDO EVAL
  INT PERIOD = *1
  INT PERIOD OK = *1
  HEAT BAL CHECK
  END HEAT BAL
  VDU UPDATE
  STATUS LAMP SET UP
  SAVE 3036
  REPLAY PHASE
  CMD 22 SENT 18 H 42 M 2 S 873 MS
  REPLAY DATA 18 H 43 M 0 S
  CMD TO BE SENT
  REG A SELECTED
  CMDS SENT
  SECOND CMD TO BE SENT
  REG B SELECTED
  CMDS SENT
  END CMDS
  END OF REPLAY DATA
```

```
   CMD 2 SENT
   DIRECT DATA
   SAVE 3186
   RPLY CMD PHASE CMD VERIFY
   REG A SEL
   CMD VERIFY OK
   EXECUTE SENT 18 H 46 M 11S 221 MS
   XCUTE VERIFIED
   REG B SEL
   CMD VERIFY OK
   EXECUTE SENT 18 H 46 M 24 S 762 MS
   ZERO DEG CMDED
   A CHANGE HAS OCCURRED
   XCUTE VERIFIED
   END REPLAY CMD VERIFY
   SAVE 5856
   A.C.S. PHASE 2
   G.J. STATUS OK
   MODE OK
   GYRO STATUS OK
   SS PRESENCE OK
   STATUS LAMP SET UP
   SAVE 3395
   PLANNED CMD PHASE
   END OF PHASE
   STATUS LAMP SET UP
   SAVE 72
   DIRECT COMMAND PHASE
   TYPE GO N WHERE N = CMD NUMBER
   STOP
   STOPPED BEFORE BOX 79
I  GO34
   CONFRM BAT MAIN CHGE ON REQD
I  YES
   19 H 46 M 56 S
   CMD RXD OK
   ANY MORE CMDS?
I  NO
   A.C.S. PHASE 3
```

```
  MODE OK
  GJ STATUS OK
  SAVE 3514
  UPDATING REG A
  TYPE CMD PATTERN IN OCTAL
I *100400
  TYPE NUMBER OF BITS IN DEC
I 9
  *100400 9 OK?
I YES
  REG A SELECTED
  CMD OK REG A = *402
  UPDATING REG B
  TYPE CMD PATTERN IN OCTAL
I *037740
  TYPE NUMBER OF BITS IN DEC
I 11
  *37740 11 OK?
I YES
  REG B SELECTED
  CMD OK REG B = *777
  END PHASE NO EXECUTES SENT
  VDU UPDATE
  SAVE 3971
  RECORD PHASE
  NO T/R CHANGE REQUIRED
  STATUS LAMP SET UP
  CMDING RECORD MODE
  RECORD TIME 18 H 52 M 36 S 11 MS
  RECORD SELECTED
  RECORD MODE
  L.O.S. AT 18 H 52 M 52 S
  STOP
  STOPPED BEFORE BOX 4016
I T
```

E.4 POST-PASS PROGRAM INSTRUCTIONS

```
    NEXT JOB
I 15,RLK
I XP
  XEQ
  X4 ROUTINE LOOK ANALYSIS

  WHICH PASS ON MAG. TAPE
I 1

  WHICH ELEMENTS
I SDC2

  LOAD TELEX TAPE

    NEXT JOB
I 15,QLK
I XP
  XEQ
  X4 QUICK LOOK ANALYSIS

  WHICH PASS ON MAG. TAPE
I 1

    NEXT JOB
I 15,ELK
I XP
  XEQ

  EMERGENCY LOOK PROGRAM

  WHICH PASS ON MAG. TAPE
I 1

  ARE SPECIFIC FRAMES RQD
  Y - - YES
  N - - NO

I Y

  TYPE IN STARTING VALUE OF FULL COUNT

  1

  TYPE IN NO. OF FRAMES OF OUTPUT
  325

  TYPE IN COLUMNS AS SHOWN
  SYLL NO. (OCTAL)
  M.F. NO. (0- - 7 OR A)
  O IF OCTAL OUTPUT RQD.
  THEN TYPE C TO COMPUTE

   XXX X O

I *025 A O
I C

  R - - - RESTART
  T - - - TERMINATE
I R

  ARE SPECIFIC FRAMES RQD.
  Y - - - YES
  N - - - NO
I N
```

```
  TYPE IN COLUMNS AS SHOWN
  SYLL NO. (OCTAL)
  M.F. NO. (0 - - 7 OR A)
  0 IF OCTAL OUTPUT RQD.
  THEN TYPE C TO COMPUTER

   XXX X 0

I *021 A 0
I *026 A 0
I *042 A 0
I *043 A 0
I *044 A 0
I *065 A 0
I *066 A 0
I *067 A 0
I *030 A 0
I *031 A 0
I *032 A 0
I *075 A 0
I *076 A 0
I *035 A 0
I C

  R - - - RESTART
  T - - - TERMINATE
I T

    NEXT JOB
I 15,WLK
I XP
  XEQ

  PROGRAM TO LIST SELECTED X4 A.C.S. PARAMETERS

  WHICH PASS ON MAG. TAPE
I 1

  TYPE IN STARTING VALUE OF FULL COUNT
  1

  TYPE IN NO. OF FRAMES OF OUTPUT
325

  TYPE SYLLABLE NOS (OCTAL)
  THEN TYPE C TO CONTINUE

I C

  INTEGRATOR OR ALBEDO VALUES  Y - - YES
                               N - - NO

  Y

  TYPE IN OTHER SYLLABLES (OCTAL)
  THEN TYPE C TO CONTINUE.

I *065
I *066
I *067
I *027
I *026
I C
```

```
   NEXT JOB
I 4,OWN14
I 7,OWN15
I 15,PAL2
I XP
  XEQ
  X4 PAL PROGRAM (PAL2)
  ELEMENTS ARE FOR DAY 123 - IS THIS OK - TYPE Y OR N
Y
  IS IT O.K. TO VALIDATE THE LAST RUN - TYPE Y OR N
Y
  CAN EXISTING SENSOR FLAGS BE USED - TYPE Y OR N
Y
  WHICH PASS ON MAG. TAPE
I 1
  NORMAL EXIT AT END OF PAL2 SUCCESSFULLY REACHED
   NEXT JOB
```

Appendix F

SOFTWARE ACTION AND TEST SPECIFICATION

Name	Definition	Domain of parameters	Remarks (see also)
ADDR	ADDR (r,n). Adds the number 'n' to the register 'r'	$1 \leqslant r \leqslant 200$ $-32768 \leqslant 32767$	SUBR, SETR, S-TO-R, SLICER
BELL	BELL rings the bell on the teletype		TREPLY
CALL	CALL (n). Stacks the box identification of the box following the one containing this action and the evaluation continues from the box with identification 'n'	'n' is a box identification	RETURN
CARRIER	If 'n' = 1 (CARRIER (n,ℓ)), will select stations 'ℓ' and turn the carrier ON at station 'ℓ'. If 'n' = 0 carrier (n,ℓ) will select station 'ℓ' and turn carrier OFF at station 'ℓ'.	'n' = 1 (on) or 'n' = 0 (off) and 'ℓ' = 1 (Lasham) 'ℓ' = 0 (Farnborough)	SEND CMD
CLRFLG	CLRFLG (f). Sets flag 'f' to 'False'	$1 \leqslant f \leqslant 200$	TFLAG, SETFLG
CMPR	CMPR (r) replaces the contents of register 'r' by its complement	$1 \leqslant r \leqslant 200$	RSHIFTR, SLICER, TBIT
COUNTR	COUNTR (n) sets register 'n' to the value of the 12 bit frame count for the frame in the minor frame buffer	$1 \leqslant n \leqslant 1000$	GETMF, GETMFN
EOF	EOF (u) writes an end of file mark on logical unit 'u'. Note that EOF (6) must not be used when data are flowing		REWIND, GODATA, STPDATA

Name	Definition	Domain of parameters	Remarks (see also)
GETMF	After GETMF the minor frame buffer will contain the good minor frame that arrived in the last ½ second. Note that if lock is lost or the data are not flowing there will not be a minor frame that arrived in the last ½ second. In this case no exit will be made from GETMF until such a frame does exist		SETUP TLOCK, GODATA, STPDATA
GETMFN	After GETMFN (n) the minor frame buffer will contain the good minor frame number 'n' that arrived in the last minor frame period (½ second)	$0 \leqslant n \leqslant 7$	GETMF
GODATA	GODATA starts the flow of telemetry data to the computer. When data are flowing it will be written on logical unit 6 and GETMF may be used to sample data. Logical unit 6 will usually be assigned to a magnetic tape		TLOCK, SETUP, GETMF, STPDATA REWIND, EOF
ICOUNT	ICOUNT (c) adds one to count word number 'c'	$1 \leqslant c \leqslant 10$	SCOUNT, TCOUNT
INR	INR (r) reads a number from logical unit one and puts it in register number 'r'	$1 \leqslant r \leqslant 200$	POCT, PDEC, OUT, PMESS
INREC	INREC (r) reads a record from the teletype to record store number 'r'	$1 \leqslant r \leqslant 5$	OUTREC
INTIME	INTIME (t) reads one record from the teletype and decodes it as a time of day. This time is then stored in time word number 't'	$1 \leqslant t \leqslant 10$	TIME

Name	Definition	Domain of parameters	Remarks (see also)
OUT	OUT (u) writes the output buffer to logical unit 'u'. The output buffer is then reset		PMESS, POCT, PDEC, PTIME, PDAY
OUTREC	OUTREC (r,u) outputs record store 'r' to logical unit 'u'	$1 \leqslant r \leqslant 5$	INREC
PDAY	PDAY appends the day number to output buffer		PMESS, OUT, POCT, PDEC, PTIME
PDEC	PDEC (n) appends the decimal representation of the number 'n' to the output buffer	$-32768 \leqslant n \leqslant 32767$	POCT, OUT, PMESS
PMESS	PMESS (m) appends the message 'm' to the output buffer	'm' is a string of one to 14 characters from the alphabet (A,B,...,Z,0,1,...9) (space, +,-,$,comma,point,/,?,=,*)	OUT, POCT, PDEC, PTIME, PDAY
POCT	POCT (n) append the octal representation of 'n' to the output buffer	$-32768 \leqslant n \leqslant 32767$	PDEC, OUT, PMESS
PTIME	PTIME appends the time of day in hours, minutes and seconds to the output of buffer		OUT, PMESS, POCT, PDEC, PDAY, PTIME 2
PTIME 2	PTIME 2 appends the time of day in hours, minutes, seconds and milliseconds to the output buffer		OUT, PMESS, POCT, PDEC, PTIME, PDAY
PULSER (N)	PULSER (N) switches replay 'N' in the relay buffer unit ON, waits one second and switches it OFF again. This is equivalent to the following flow chart actions:- Rbuff (N,1) Wait (1) Rbuff (N,0)	$1 \leqslant N \leqslant 64$	RBUFF, WAIT

Name	Definition	Domain of parameters	Remarks (see also)
RBUFF	RBUFF (r,n) switches relay 'r' ON if 'n' = 1 and OFF if 'n' = 0. Relays are numbered down the column, and going from left to right (column 1-8) i.e. Column 1 = relays 1-8 " 2 = " 9-16 " " " " " " " 8 = " 57-64	$1 \leqslant r \leqslant 64$ 'n' = 1 or 'n' = 0	
RESTORE	RESTORE returns from SDC2 (LU8) the values saved by the last SAVE. It will change the contents of the registers, the flags, the count words, the record stores and the time words to their values at the last SAVE made		SAVE
RETURN	RETURN unstacks a box identification and the evaluation continues from the box this identifies. If the stack is empty, RETURN behaves like STOP		CALL, STOP
REWIND	REWIND (u) rewinds logical unit 'u'. Note that REWIND (6) must not be used when data are flowing	u = 2 for the teletype	GODATA, STPDATA, EOF
RSHIFTR	For 'n' positive RSHIFTR (r,n) shifts register 'r' right by 'n' places. For 'n' negative RSHIFTR (r,n) shifts register 'r' left by 'n' places	$-16 \leqslant n \leqslant 16$ $1 \leqslant r \leqslant 200$	SLICER, TBIT, CMPR

Name	Definition	Domain of parameters	Remarks (see also)
SAVE	SAVE stores some of current values from FLINT on to SDC2 (LU8). The values stored are the contents of the registers, the flags, the count words, the record stores and the time words		RESTORE
SCLOCK	SCLOCK (c) starts software clock number 'c'	$1 \leqslant c \leqslant 10$	TCLOCK, WAIT
SCOUNT	SCOUNT (c) sets count word 'c' to one	$1 \leqslant c \leqslant 10$	ICOUNT, TCOUNT
SENDCMD	SENDCMD (c,a,f) sends command 'c' with address 'a' in format 'f' to the selected command station	$1 \leqslant c \leqslant 70$ a = 0 = X3 address A a = 1 = X4 address A a = 2 = X4 address B a = 3 = X3 address B f = 5 = 5 word format f = 2 = 2 word format	CARRIER
SETEW	SETEW (w,n) sets extra word 'w' to the number 'n' and on exit at least one frame will have been written with extra word 'w' set to 'n'	$1 \leqslant w \leqslant 10$ $-32768 \leqslant n \leqslant 32767$	
SETFLG	SETFLG (f) sets flag 'f' to 'true'	$1 \leqslant f \leqslant 200$	TFLAG, CLRFLG
SETR	SETR (r,n) makes the contents of register 'r' the number 'n'	$1 \leqslant r \leqslant 200$ $-32768 \leqslant n \leqslant 32767$	ADDR, SUBR, S-TO-R, SLICER
SETUP	SETUP sets up the telemetry equipment to receive X4 telemetry data		TCLOCK, GODATA, GETMF, STPDATA
SLICER	SLICER (r,n,u,ℓ) sets bits one to $u - \ell + 1$ of register 'r' to bits u to ℓ of number 'n'. The upper $16 - (u - \ell + 1)$ bits of 'r' will be zeros.	$1 \leqslant r \leqslant 200$ $-32768 \leqslant n \leqslant 32767$ $1 \leqslant \ell \leqslant u \leqslant 16$	SETR, S-TO-R, SUBR, RSHIFTR SLICER, TBIT

ACTIONS

Name	Definition	Domain of parameters	Remarks (see also)
STOP	STOP types 'STOP' on the teletype and the evaluation stops.		
STPDATA	STPDATA stops the flow of telemetry data to the computer.		TLOCK, SETUP, GODATA, GETMF, REWIND, EOF
SUBR	SUBR (r,n) subtracts the number 'n' from register 'r'.	$1 \leqslant r \leqslant 200$ $-32768 \leqslant n \leqslant 32767$	SETR, ADDR, S-TO-R, SLICER
S-TO-R	S-TO-R (r,s) sets register 'r' to the value of syllable 's'	$1 \leqslant r \leqslant 200$ $4 \leqslant s \leqslant 127$	SETR, ADDR, SUBR, SLICER
WAIT	WAIT (s) waits for 's' seconds.	$1 \leqslant s \leqslant 32767$	SCLOCK, TCLOCK

TESTS

Name	Definition	Domain of parameters	Remarks (see also)
TBIT	TBIT (n,b) returns 'true' if bit 'b' of the 16 bit number 'n' is one and returns 'false' otherwise.	$1 \leq b \leq 16$ $-32768 \leq n \leq 32767$	TMF, TSYL, GETMF
TCLOCK	TCLOCK (c,s) returns 'true' if software clock number 'c' has been running for greater than or equal to 's' seconds, otherwise it returns 'false'.	$1 \leq c \leq 10$ $0 \leq s \leq 32767$	SCLOCK, WAIT
TCOUNT	TCOUNT (c,n) returns 'true' if count word 'c' equals 'n' and returns 'false' otherwise.	$1 \leq c \leq 10$ and $1 \leq n \leq 32767$	SCOUNT, ICOUNT
TEQ	TEQ (m,n) returns 'true' if the number 'm' equals the number 'n' and returns 'false' otherwise.	$-32768 \leq m \leq 32767$ $-32768 \leq n \leq 32767$	TBIT, TLIMIT
TFLAG	TFLAG (f) returns 'true' if flag 'f' is 'true' and returns 'false' otherwise.	$1 \leq f \leq 200$	SETFLG, CLRFLG
TGOODS	TGOODS returns 'true' if the telemetry receiving station indicates good signal and returns 'false' otherwise.		
TLIMIT	TLIMIT (n,ℓ,u) returns 'true' if the number 'n' is greater than or equal to 'ℓ' and less than or equal to 'u'.	$-32768 \leq \ell \leq u \leq 32767$ $-32768 \leq n \leq 32767$	TBIT, TMF, GETMF
TLOCK	TLOCK returns 'true' if the telemetry equipment is in lock and 'false' otherwise		SETUP, GODATA, GETMF, STPDATA

Name	Definition	Domain of parameters	Remarks (see also)
TMF	TMF (n) returns 'true' if the frame ident of the minor frame in the minor frame buffer equals 'n' and returns 'false' otherwise. If b(1), ..., b(8) are bits of syllable 004 then the frame ident is the number $b(3) \times 4 + b(2) \times 2 + b(1)$.	$0 < n < 7$	
TREPLY	TREPLY reads lines from the teletype until one of the lines 'YES' or 'NO' is read. If the line read is 'YES' then TREPLY returns 'true'. If the line read is 'NO' then TREPLY returns 'false'. If TREPLY returns 'true' then 'YES' was typed. If REPLY returns 'false' then 'NO' was typed.		BELL
TTIME	TTIME (t) returns 'true' if the correct time of day is greater than or equal to the time of day stored in time word number 't' and returns 'false' otherwise.	$1 < t < 10$	INTIME

Appendix G

POST-PASS PROGRAMS

G.1 General

A suite of programs[10] are available to provide post-pass data on the satellite. Although the writing of these programs was not the responsibility of the authors, a brief description of the programs are included for completeness.

Those of operational importance are listed below. Many other programs were available for experimental analysis but these are beyond the scope of this Report.

G.1.1 Mandatory programs (each pass)

(a) Quick look (QLK)

Provides experimenters and subsystem designers with print out of pre-specified parameters (see Fig.G1a thru G1f).

(b) Routine look (RLK)

Provides experimenters with experimental data analysis incorporating orbital data.

(c) Pitch attitude log 2 (PAL2)

Provides a continuous record of the attitude control system performance, e.g. gas consumption, rate commands, horizon crossings, etc.

G.1.2 Programs as requested

(a) Star lock/look (SLK)

This program determines the pitch rate commands and execute times to achieve the correct satellite attitude for a selected star (see Fig.G2).

(b) ACS parameter listing (WLK)

To output selected ACS parameters over specified periods of a pass.

(c) Emergency look (ELK)

To output decimal or octal listings of selected parameters with extra word values. Note:- Extra words (written to digital tape and originating from the real time program) are used by PAL2 and contain information about ACS commands (e.g. cmd pattern sent; ACS register used; whether execute command verified).

Fig.G3 shows requirements for each of the 'look' programs.

G.1.3 Miscellaneous programs

(a) Program for look angle predictions (PLAP)

This program provides tracking information of time, azimuth elevation bearings for specified days. It is run weekly for use by the CC and ground station. An option is available for a punched paper tape output for control of the LTS1 aerial. The orbital elements for use in the program are provided from MOD sources.

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5	G.W. Brown P. Haskell	Final report on the star sensor experiment in the Miranda satellite. RAE Technical Report to be published.
6	M.B. Barnes S. Craig A. Haskell	Satellite X4: the infra-red experiment. RAE Technical Report to be published.
7	A.K. Brookman M.J. Pearson	Satellite X4: the 100 element self-scanned photodiode array. RAE Technical Report 73195 (1974)
8	M.J. Hammond E.A.R. Anstey E. Jones	Miranda: operations for two electronically disturbed passes. RAE Technical Report 76017 (1976)
9	W.G. Hughes	Operational experience of the Miranda (X4) satellite attitude control system. RAE Technical Report 75116 (1975)
10	E.U. Trevorrow	Miranda data processing. RAE Technical Report in preparation.

Reports quoted are not necessarily available to members of the public or to commercial organisations.

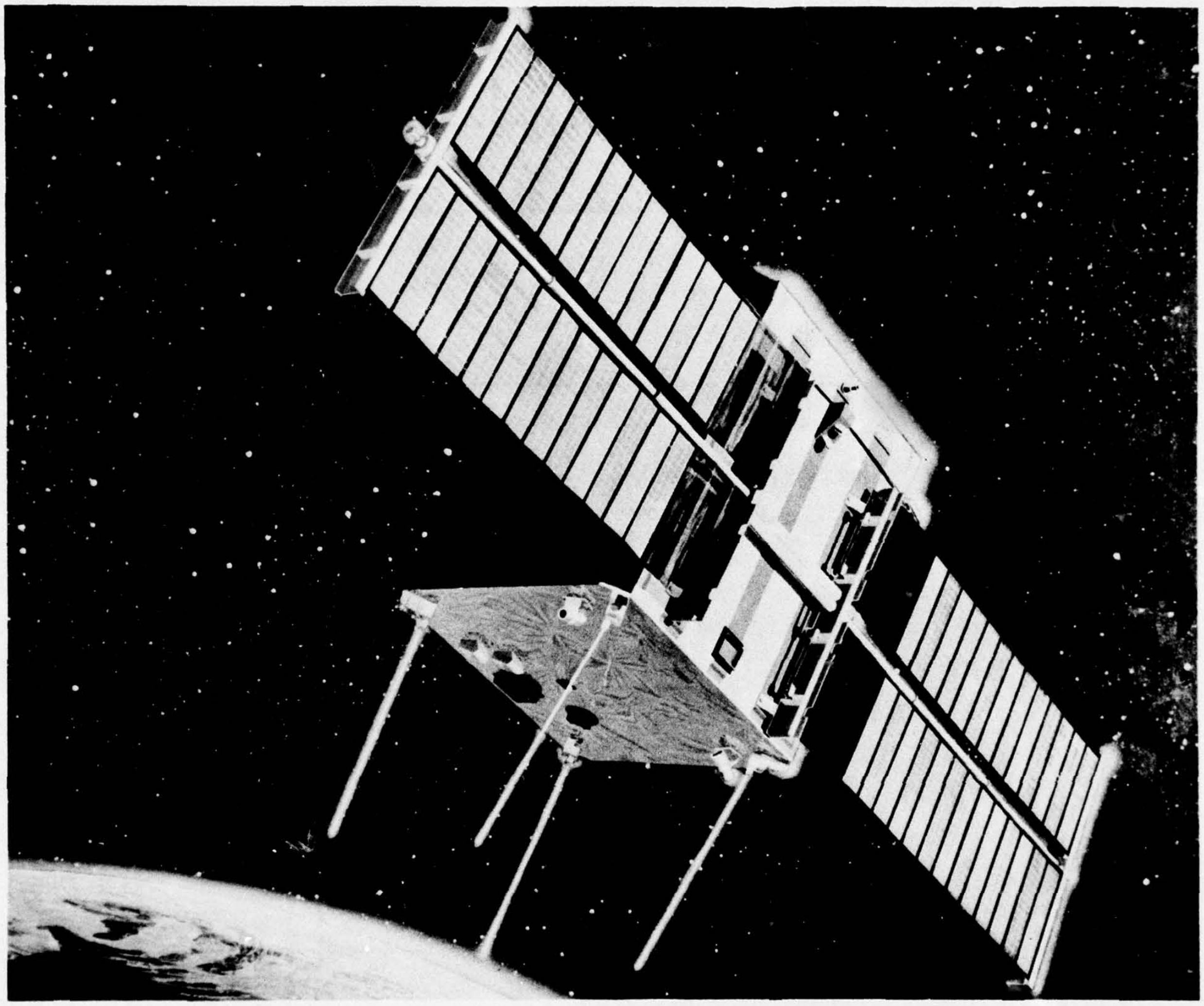
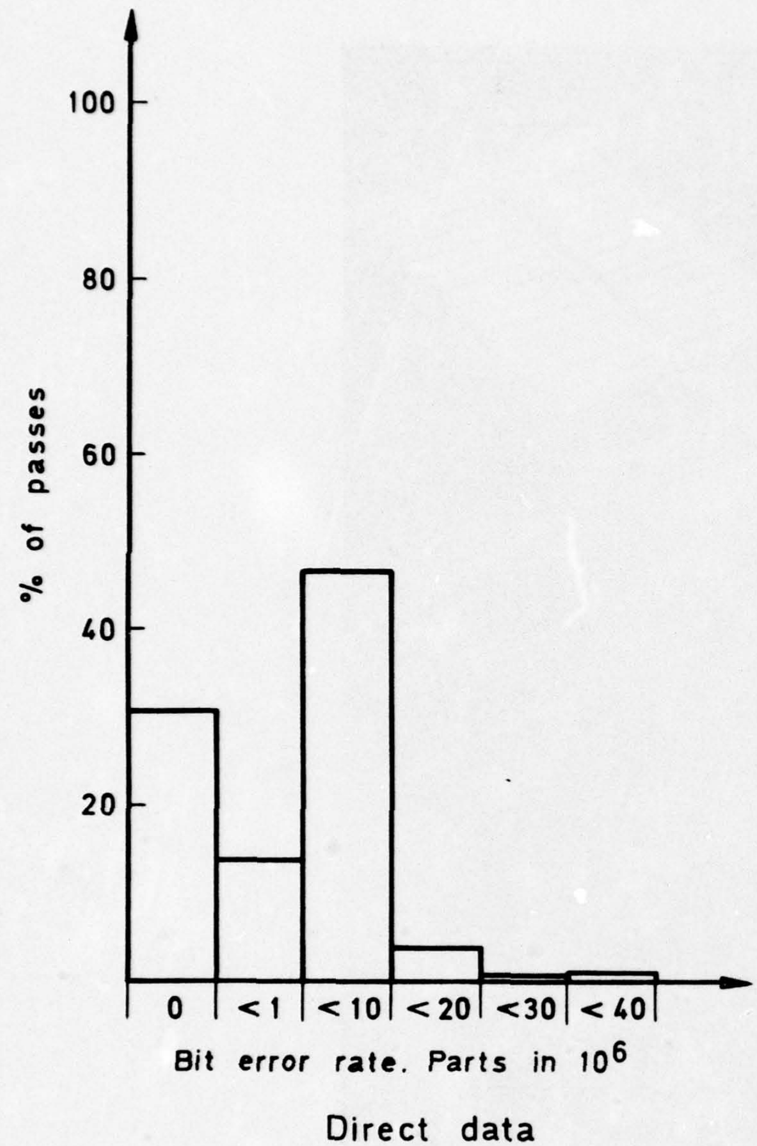


Fig.1 Miranda in orbit



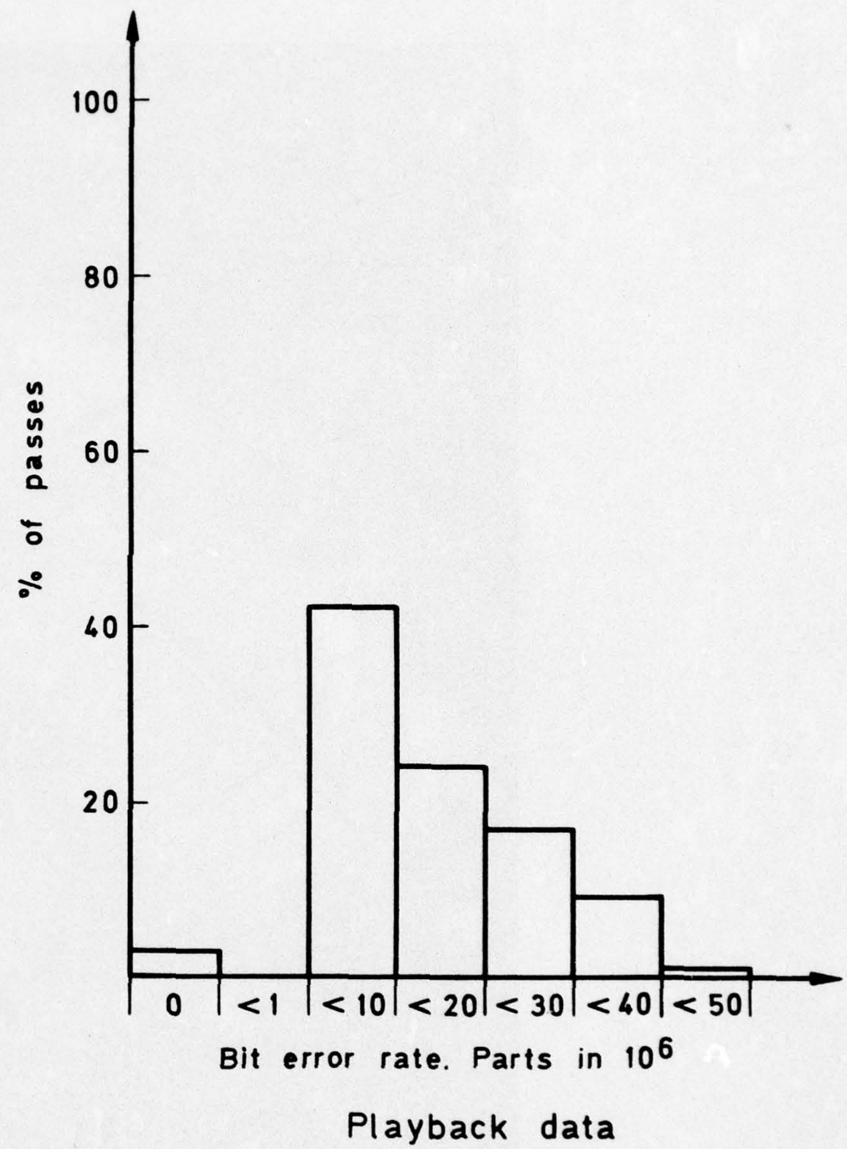


Fig. 2 Histogram showing percentage of passes against bit error rate

Fig.A1

000 SYNC	001 SYNC	002 SYNC + 1	003 DD60	004 DD00	005 DD10	006 DD30	007 DD40	DIGITAL (DATA HANDLING)
010 CG01	011 CG02	012 CG03	013 CG04	014 CG05	015 CP01	016 CP02	017 CP03	ANALOGUE PRIME
020 CD10	021 CD30	022 CR04	023 CR05	024 CR06	025 CD00	026 CD20	027 CR12	DIGITAL (ACS)
030 CG01	031 CG02	032 CG03	033 CG04	034 CG05	035 CS01	036 CS02	037 CG06	ANALOGUE PRIME
040 0 1 2 3 4 5 6 7	041 CT01 ↓ CT08	042 CT09 ↓ CT16	043 CT17 ↓ CT24	044 EP01 EP02 CP09 ↓ CP10	045 ES04 ES05 ET01 ET02 ES04 ES05 EP03 ET04	046 ES06 ↓ ES06	047 ES07 ↓ ES07	ANALOGUE SUB
050 CG01	051 CG02	052 CG03	053 CG04	054 CG05	055 CG07	056 CS03	057 CS04	ANALOGUE PRIME
060 CR09	061 CR10	062 CR11	063 CR18	064	065 CR01	066 CR02	067 CR03	DIGITAL (ACS)
070 CG01	071 CG02	072 CG03	073 CG04	074 CG05	075 CS05	076 CS06	077 ES01	ANALOGUE PRIME
100 DD50	101 PD00	102	103 DD20	104 ED00	105 ED10	106 ED20	107 ED30	DIGITAL
110 CG01	111 CG02	112 CG03	113 CG04	114 CG05	115 CP01	116 CP02	117 CP03	ANALOGUE PRIME
120 CD10	121 CD30	122 CR04	123 CR05	124 CR06	125 CR15	126 CR16	127 CR17	DIGITAL (ACS)
130 CG01	131 CG02	132 CG03	133 CG04	134 CG05	135 CS01	136 CS02	137 CG06	ANALOGUE PRIME
140 0 1 2 3 4 5 6 7	141 DP01 ↓ DP03 ET03 DP04 ↓ DP07	142 DP08 ↓ DP12 PT01 ↓ PT03	143 ES08 ST09 DT05 DT06 ET05 ET06	144 PC01 ↓ PC08	145 PV01 ↓ PV08	146 ST01 ↓ ST08	147 ES02 ES03 ES02 ES03 ES02 ES03 ES02 ES03	ANALOGUE SUB.
150 CG01	151 CG02	152 CG03	153 CG04	154 CG05	155 CG07	156	157 CP04	ANALOGUE PRIME
160	161 CP11	162 CP12	163 CP13	164 CP05	165 CP06	166 ES06	167 ES07	ANALOGUE PRIME
170 CG01	171 CG02	172 CG03	173 CG04	174 CG05	175	176 EP04	177 ES01	ANALOGUE PRIME

Fig.A1 Telemetry format

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Fig.B1

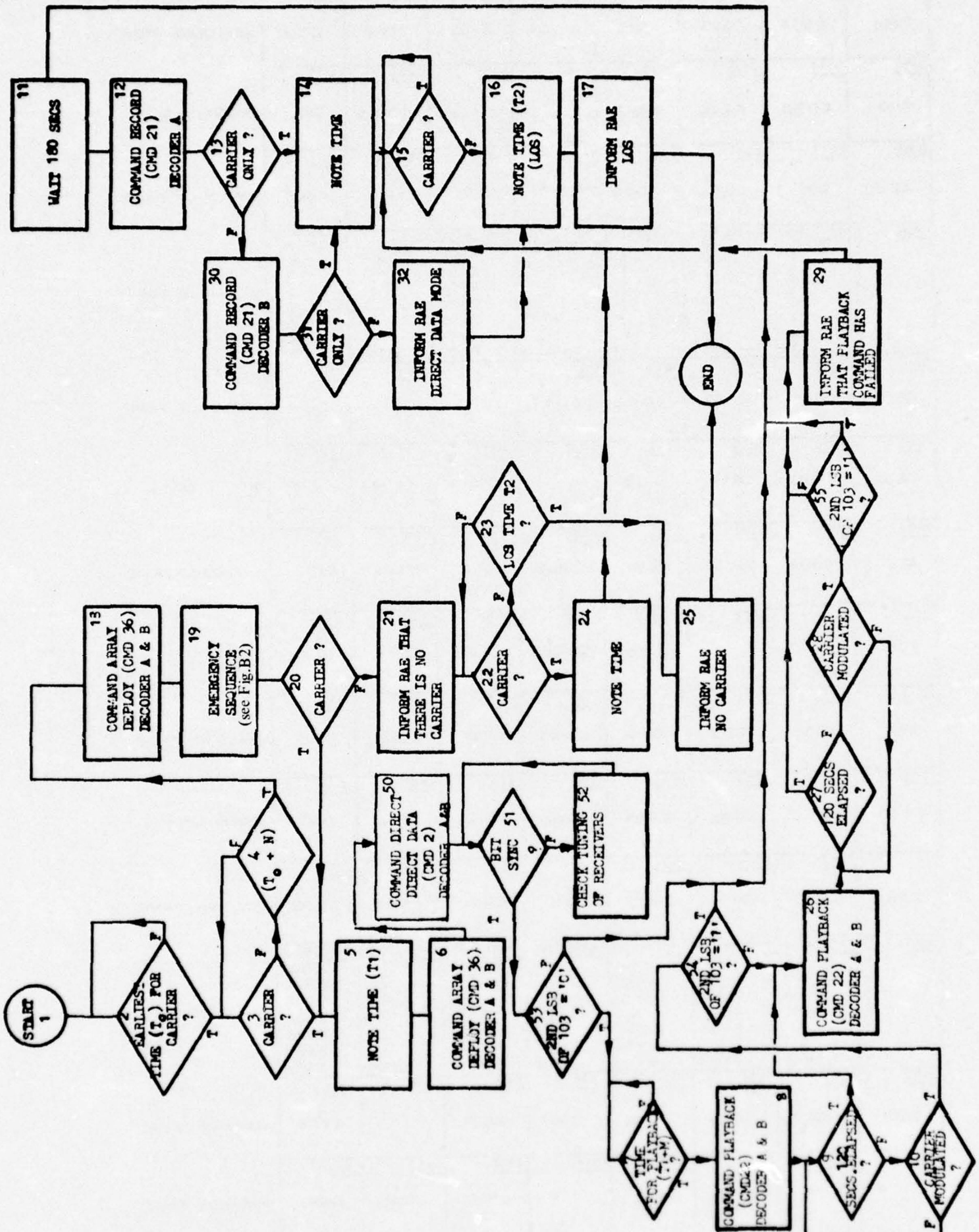

Fig.B1 Routine operations flowchart

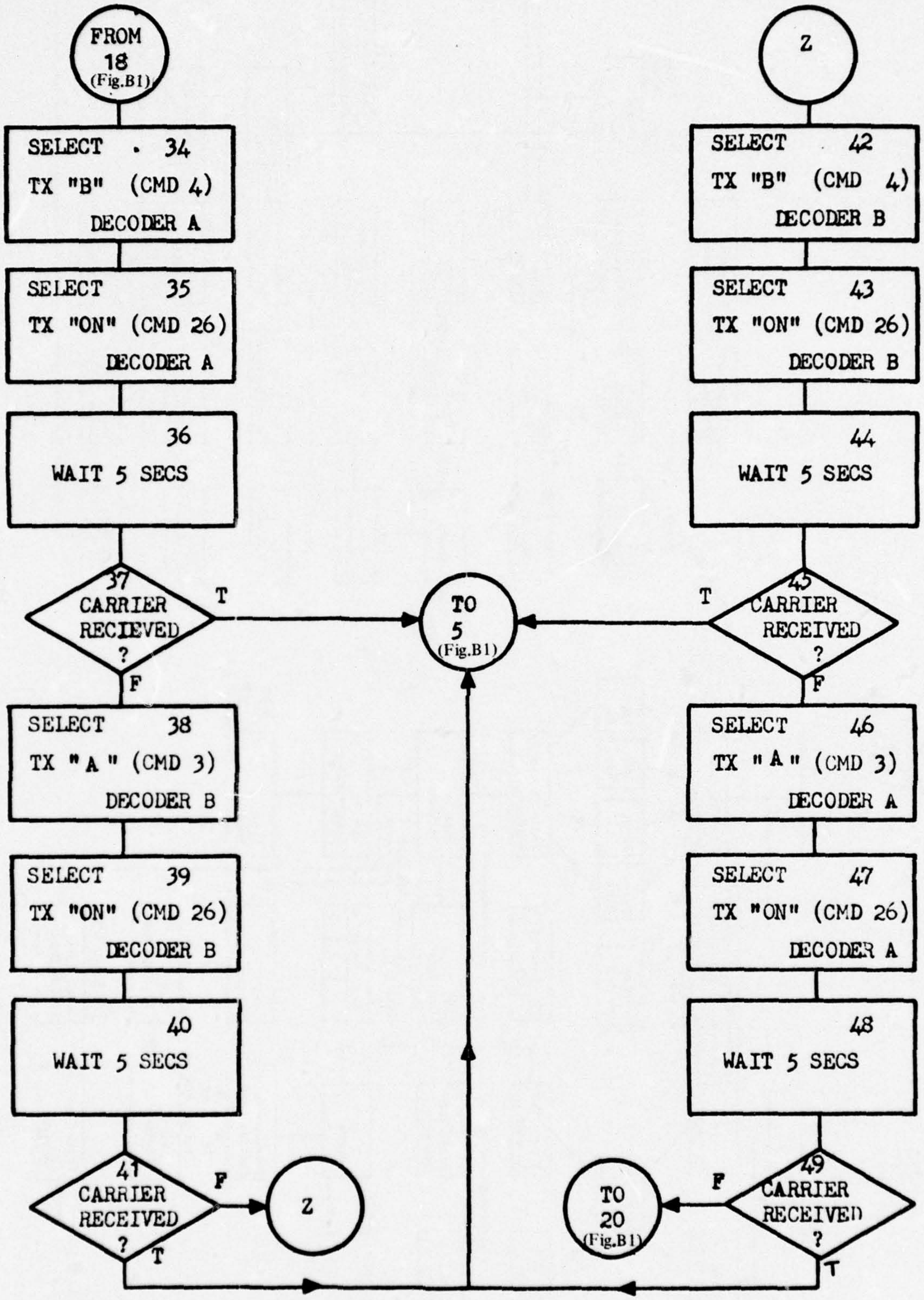

Fig.B2 Emergency sequence flowchart

Fig.C1

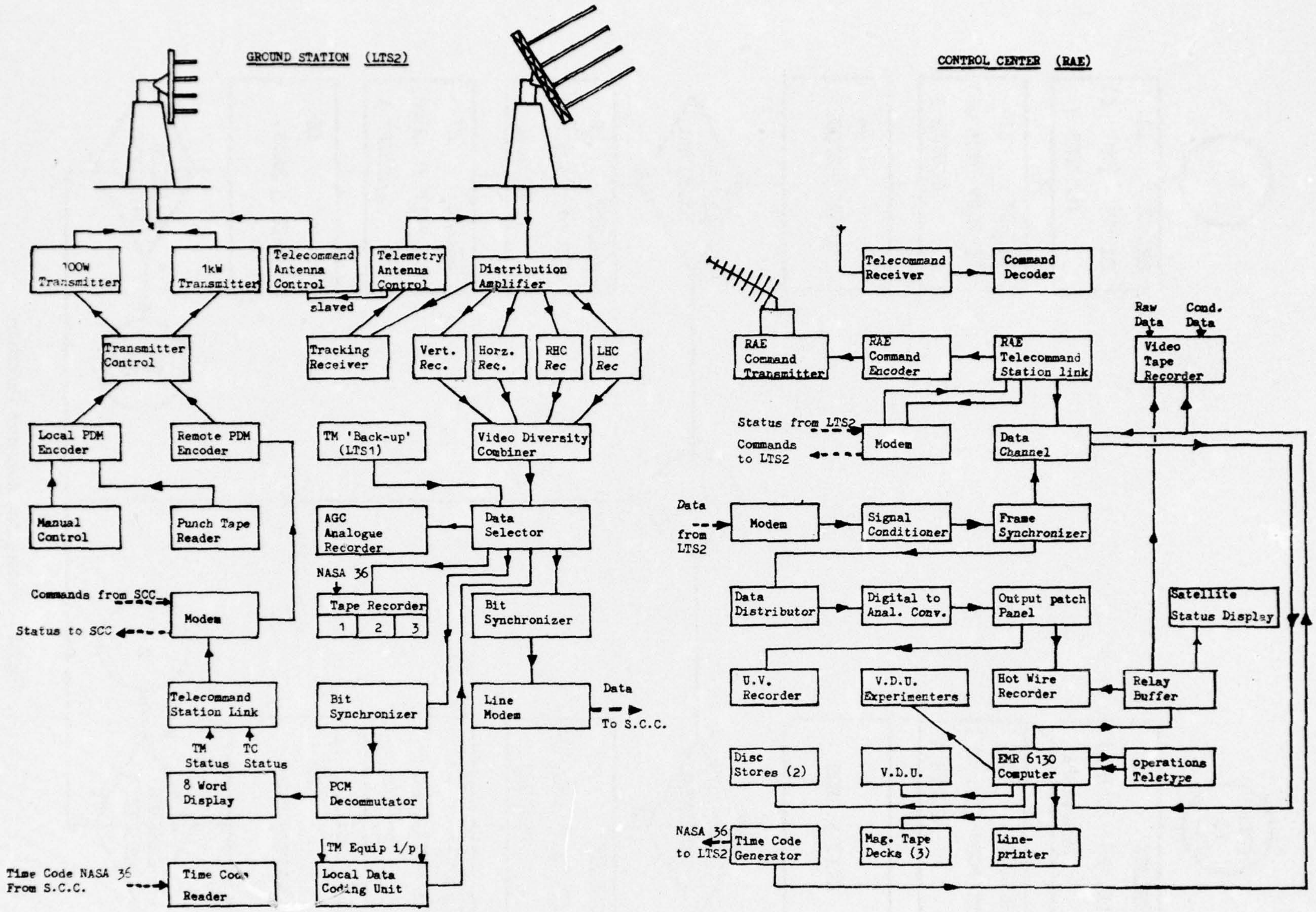

Fig.C1 Block diagram of Ground Station/Control Centre

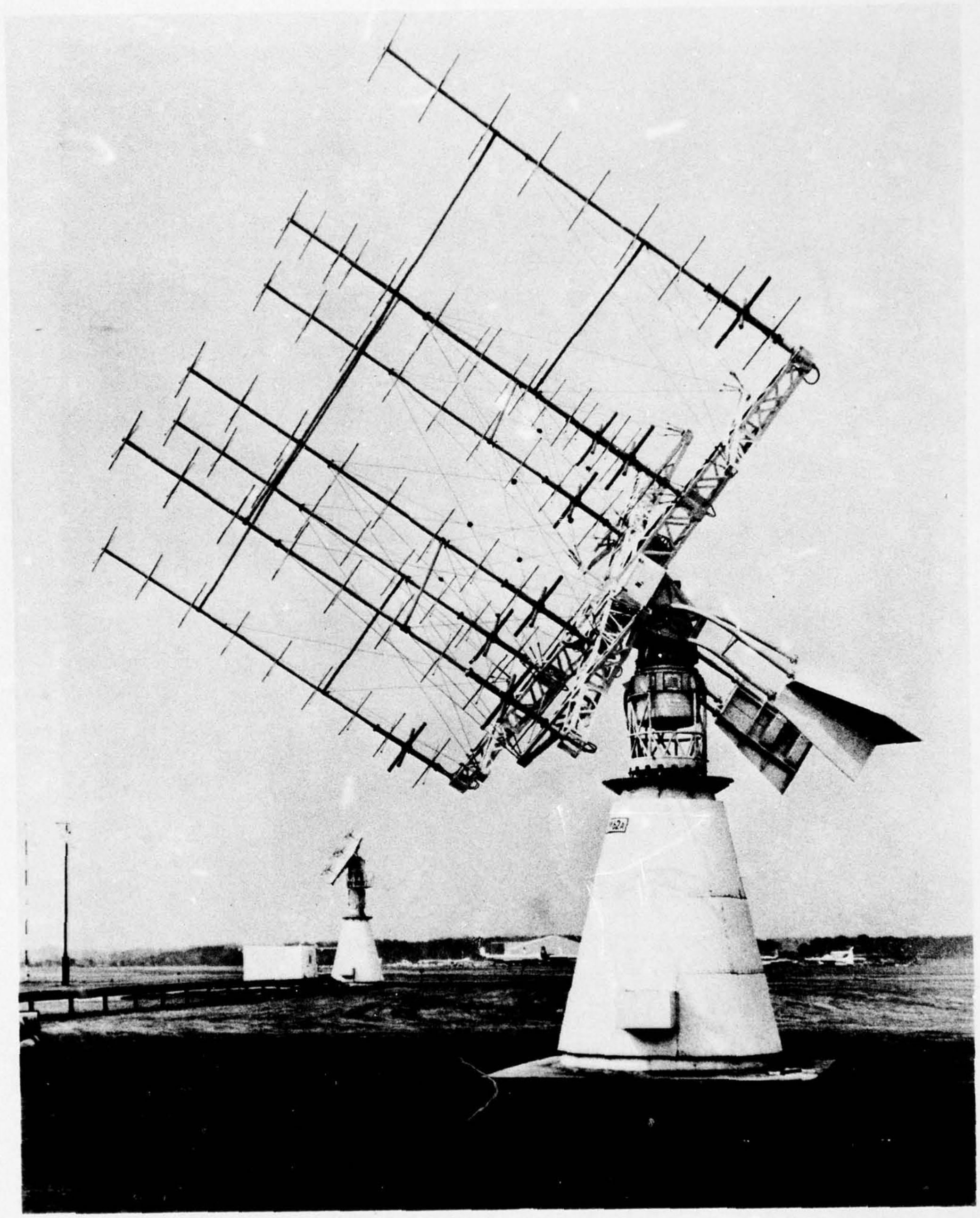

Fig.C2 Telemetry aerial (foreground)

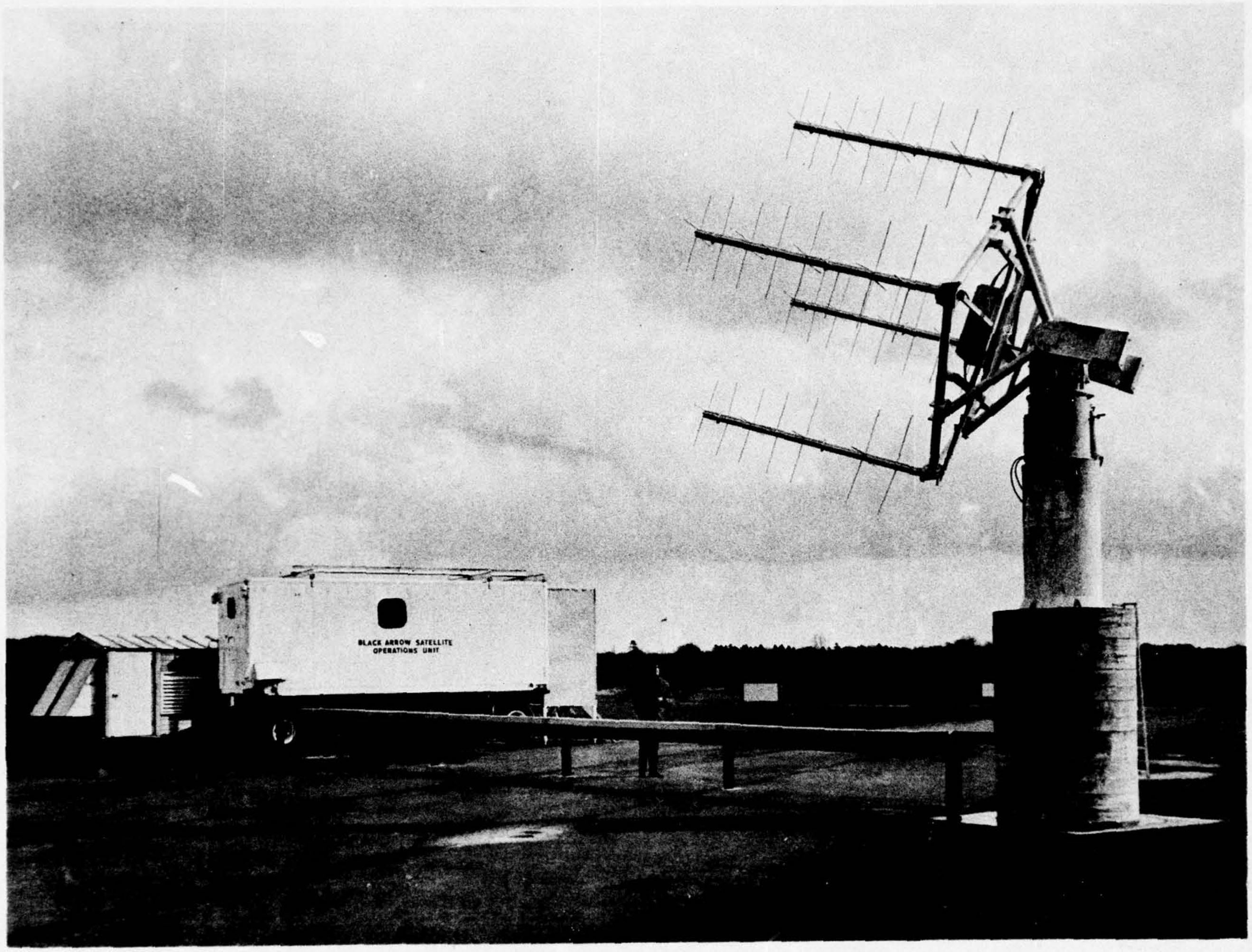

Fig.C3 Back up Telemetry Station

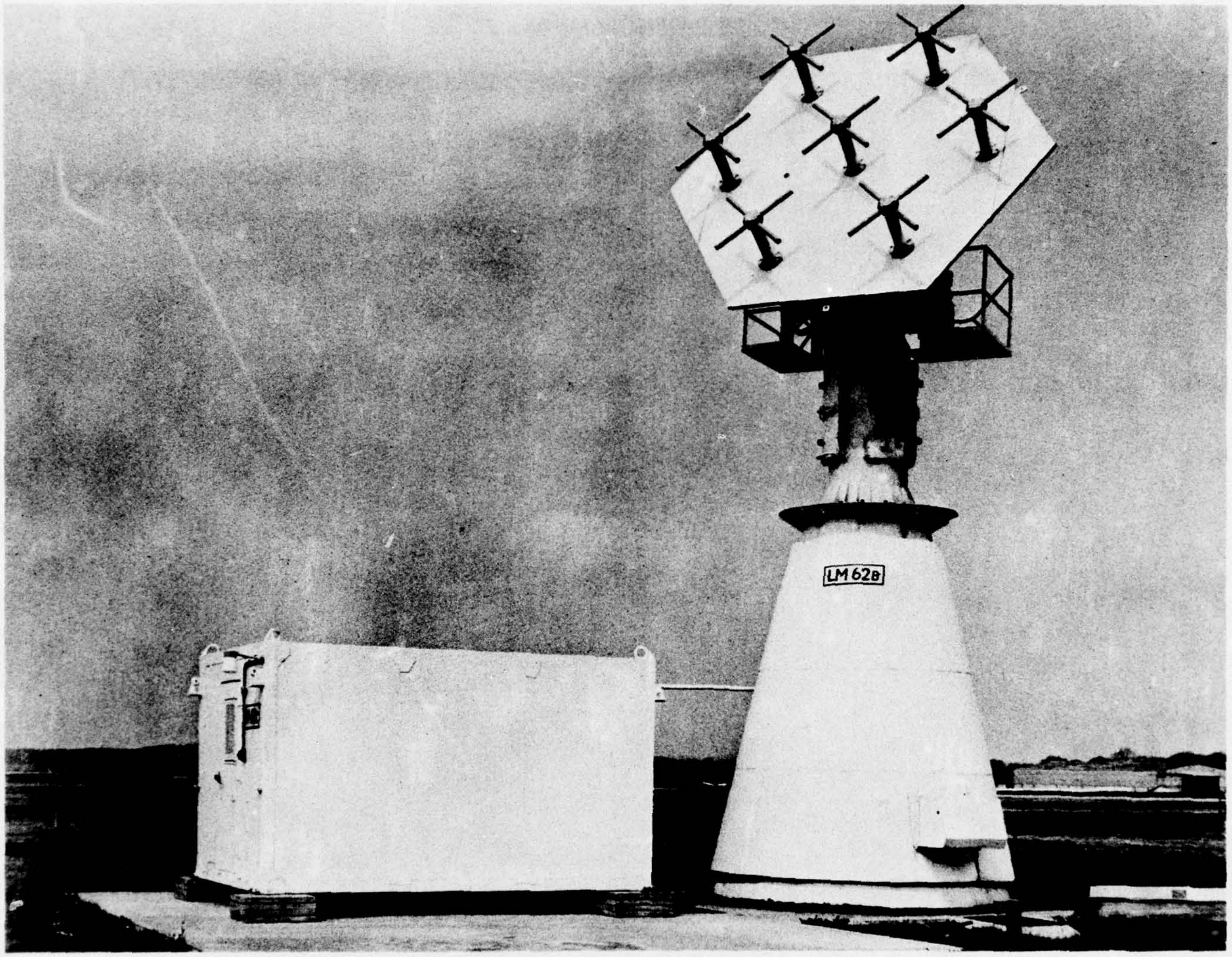

Fig.C4 Telecommand aerial

Fig.C5

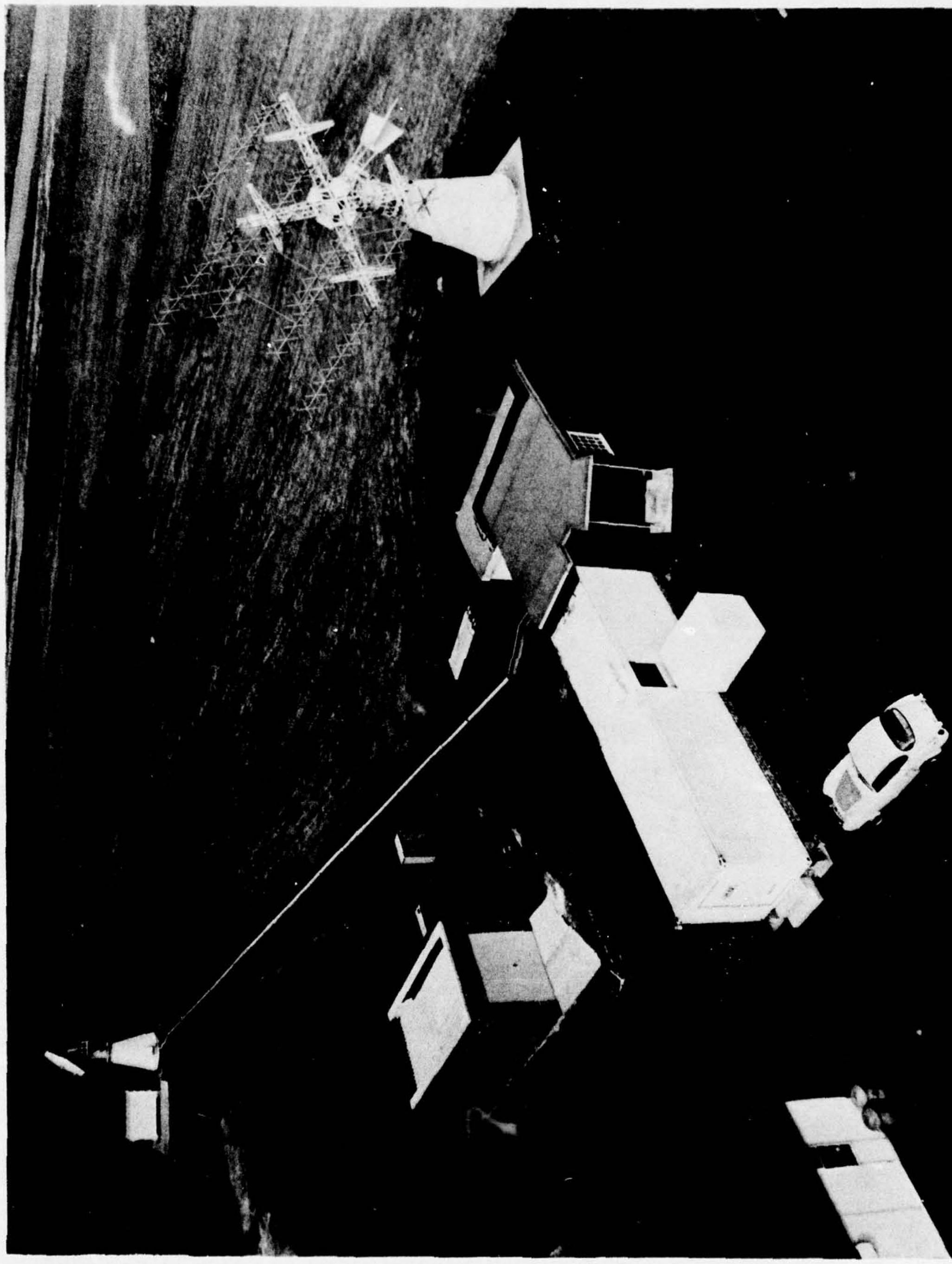

Fig.C5 View of Ground Station

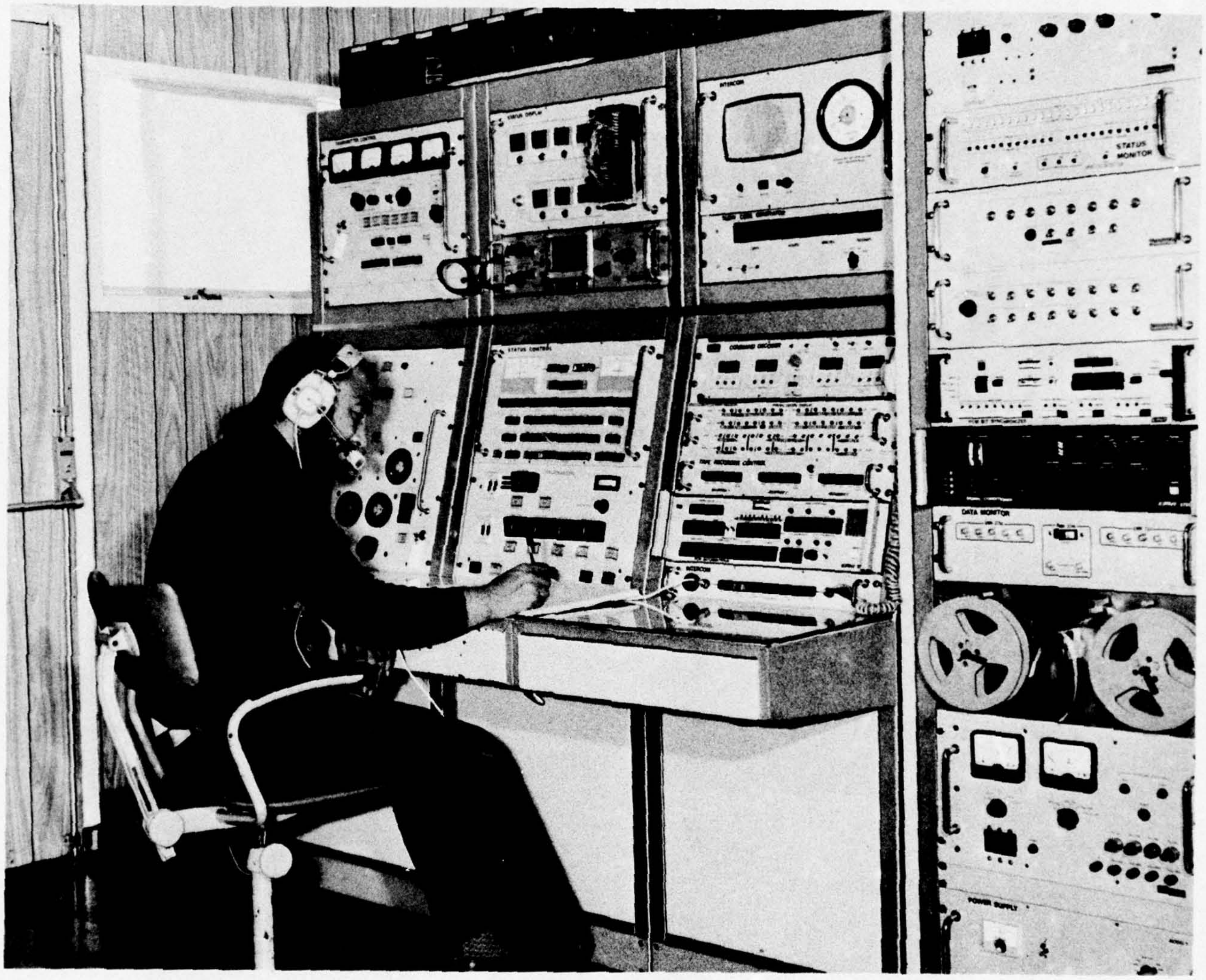

Fig.C6 Ground Station control console

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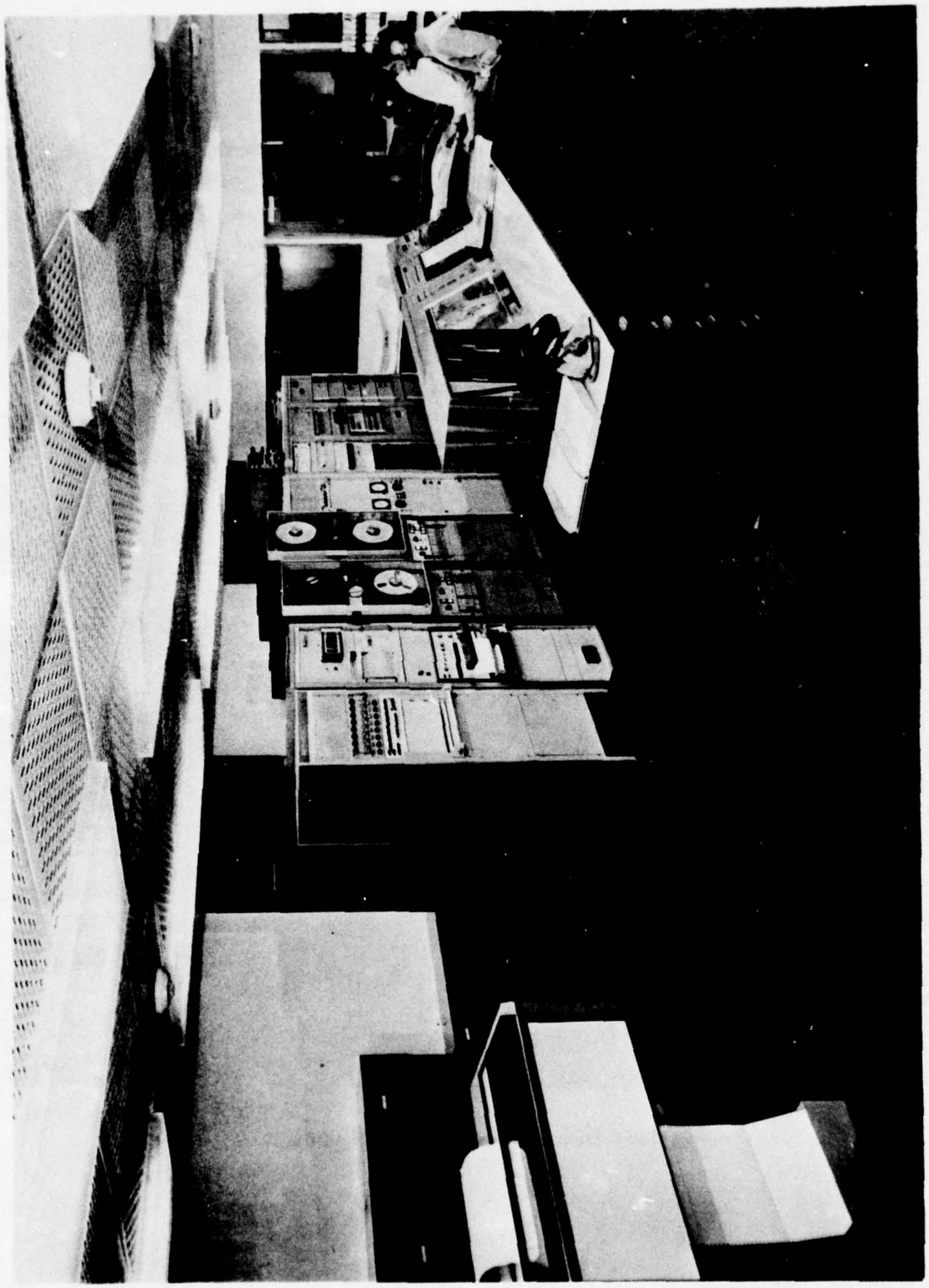

Fig.C7 Control Centre

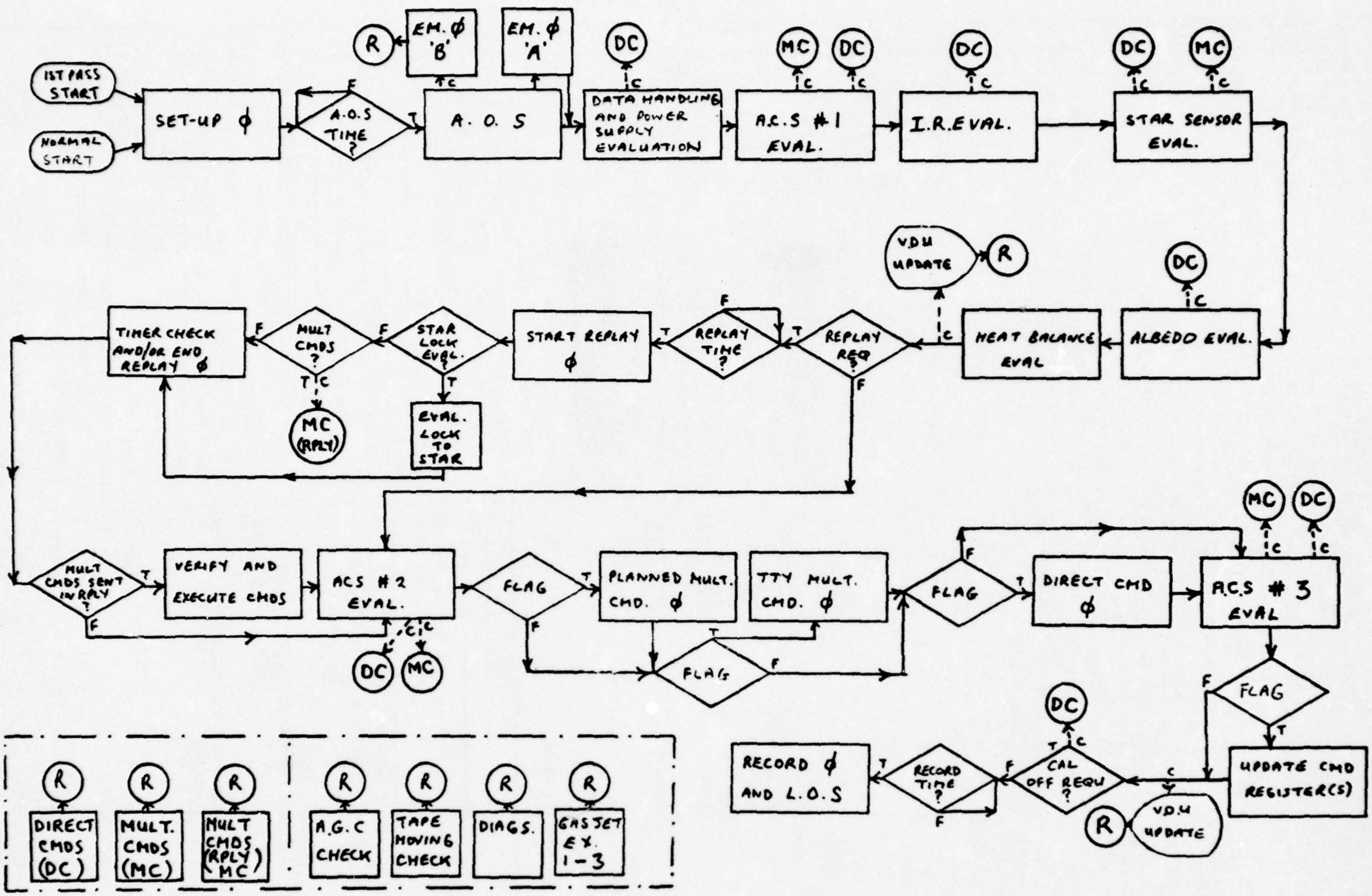

Fig.D1 Operations block diagram for Miranda

Fig.D1

Fig.D2

DAY NO. 140 | DUTY SHIFT 28A | DATE 20/5 | DIG TAPE NO. 174

HEADER.

ORBIT NO.	1 0 3 4
PASS NO.	K E X 2 X
A.O.S. TIME.	1 8 - 3 9 - 0 0
DAY NO.	1 4 0
RECORD TIME	1 7 - 1 1 - 3 6 · 0 0 6
VIDEO TAPE NO.	0 7 4

LIMITS PRINTOUT	N / VDU / LPR
LIMITS CHANGE REQ?	N

REG. NO.	NEW LIMIT	REG NO.	NEW LIMIT
	*		*
	*		*

TAPE DUMP REQ?	Y
TAPE DUMP TIME	1 8 H 4 2 M 0 0 S

POWER SUPPLY AND DATA HANDLING

ADC 'A' EXPECTED?	N
EXPTD USER SW STATUS	* 7
TR 'A' EXPECTED?	Y
EXPTD TRACK NO.	3
TR 'A' REQ NEXT PASS?	Y
NO. OF 'RECORD' CMDS.	1
TX 'A' EXPECTED?	Y
REDUNDANCY STATUS	* 0 3 3
STATUS SHEET 2.	

A.C.S. STATUS

MODE STATUS	(WORD 1)	* 0 0 0
	MODE =	3
GAS JET STATUS	(WORD 2)	* 1 0 0
GYRO STATUS	(WORD 3)	* 2 1 0
F.S.S. SELECTED?		Y

SET A.C.S. REGS AT END OF PASS?	Y
REG 'A'?	Y
REQ PATT.•	* 1 0 0 4 0 0
BITS	9
REG 'B'?	Y
REQ PATT.•	* 0 3 7 7 4 0
BITS	1 1
A.C.S. REGISTER CONTENTS CHECK REQUIRED?	Y
REG 'A'? YES ~~NO~~ EXECUTE IF CORRECT? ~~YES~~ NO	
REG 'A' PATT =	* 1 0 0 4 0 0
BITS =	9
REG 'B'? YES ~~NO~~ EXECUTE IF CORRECT? ~~YES~~ NO	
REG 'B' PATT =	* 0 3 7 7 4 0
BITS =	1 1

EXPERIMENTS

ALBEDO

SWITCH ON?	
EXPTD OR NEW INT PERIOD	* 1
INT PERIOD NEW THIS PASS?	N

I.R.

SWITCH ON?	
EXPTD OR NEW DET 3 SETTING	* 2
DET 3 NEW THIS PASS?	N
EXPTD OR NEW DET 4 SETTING	* 2
DET 4 NEW THIS PASS?	N

CANOPUS

SWITCH ON?	
IS O.E.W. SET?	N
CAL EXPTD ON?	N
LEAVE CAL ON?	
EXPTD MIRROR POSITION	* 0 6
EXPT THRESHOLD	* 3
MIRROR POSN CHANGE?	N
REQ MIRROR SETTING	*
MIRROR TO MOVE FORWARD?	
NO OF CMDS	
THRESHOLD CHANGE?	N
REQ THRESHOLD SETTING * NO OF CMDS	

WILL LASHAM BE CMD STATION?	Y
5 FORMAT CMDS REQUIRED?	Y
ANY CMDS REQUIRED?	Y
ANY MULTIPLE CMDS?	Y
1. MULTIPLE COMMAND PATTERN	* 0 0 0 3 3 2
NO OF BITS IN PATTERN (DECIMAL)	1 6
TIME DEPENDENT? N TIME	H M S
2. MULTIPLE COMMAND PATTERN	* 0 6 0 0 0 0
NO OF BITS IN PATTERN (DECIMAL)	1 1
TIME DEPENDENT? N TIME	H M S
3. MULTIPLE COMMAND PATTERN	*
NO OF BITS IN PATTERN (DECIMAL)	
TIME DEPENDENT? TIME	H M S
CMDS TO BE SENT IN REPLAY?	Y
2 CMDS REQUIRED IN REPLAY?	Y

ANY FURTHER MULTIPLE COMMANDS?	N
4. MULTIPLE COMMAND PATTERN	*
NO OF BITS IN PATTERN (DECIMAL)	
TIME DEPENDENT? TIME	H M S
5. MULTIPLE COMMAND PATTERN	*
NO OF BITS IN PATTERN (DECIMAL)	
TIME DEPENDENT? TIME	H M S
6. MULTIPLE COMMAND PATTERN	*
NO IF BITS IN PATTERN (DECIMAL)	
TIME DEPENDENT? TIME	H M S

ANY DIRECT CMDS REQUIRED? Y

CMD NO	DESCRIPTION	REMARKS
34	MAIN CHARGE	

TIMES

PASS DURATION	1 5 M
TIMER CHECK REQUIRED?	N
RECORD TIME	1 8 H 5 2 M 3 0 S
EMERGENCY TIME	1 8 H 4 2 M 0 0 S
A.O.S. TIME	1 8 H 3 8 M 0 0 S
L.O.S. TIME	1 8 H 5 5 M 0 0 S

REMARKS (MAY BE CONTINUED ON SHEET 2)

• TYPED IN DURING PASS.

1ST MULT CMD = +1.6°/h PITCH INT.

2ND MULT CMD = 0°/h PRIME RATE

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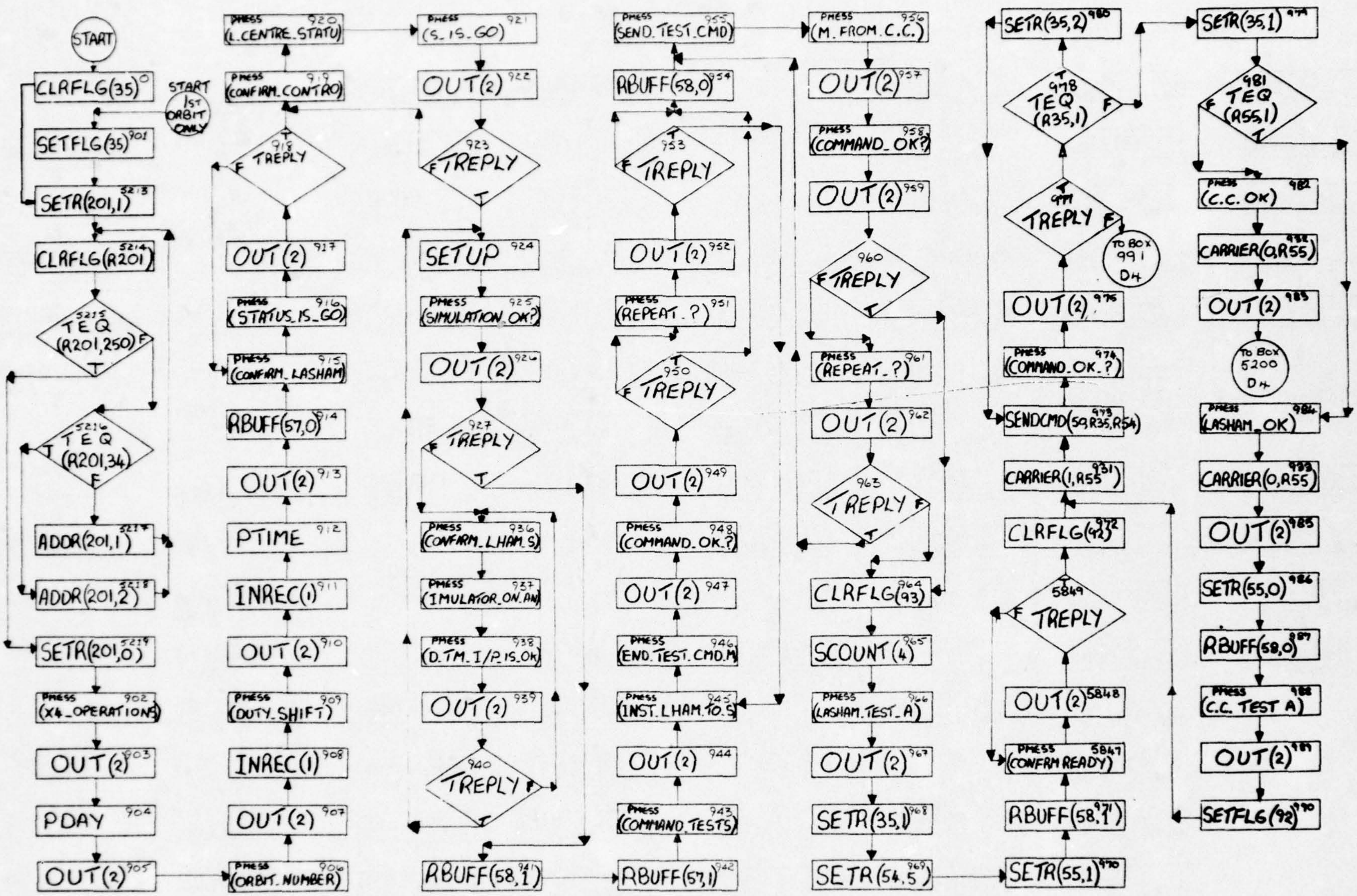
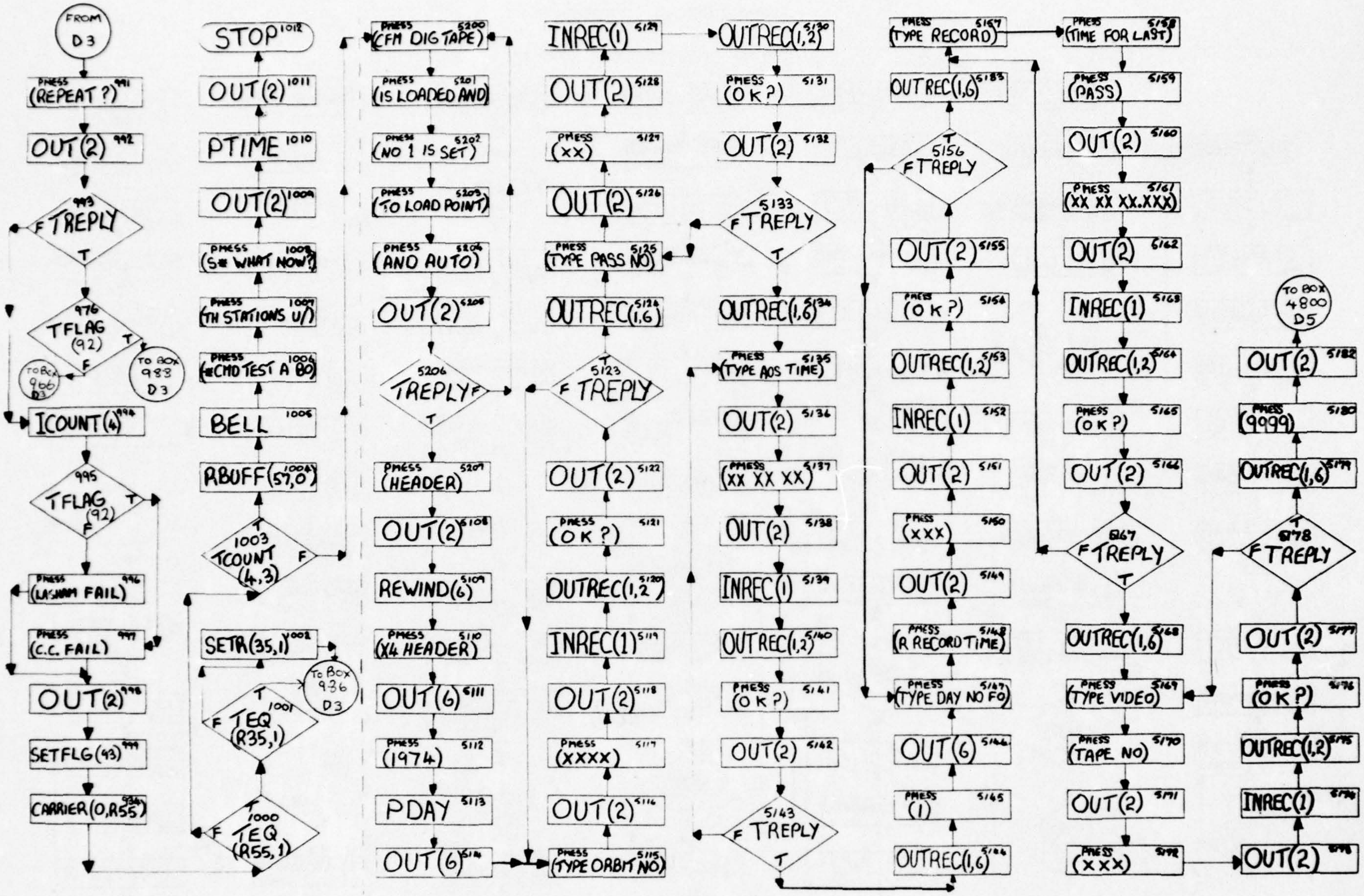
Fig.D2 X4 operations schedule



Equipment set up and command tests

Fig.D3 Set up phase

Fig.D4



Dig tape header block

Fig.D4 Set up phase

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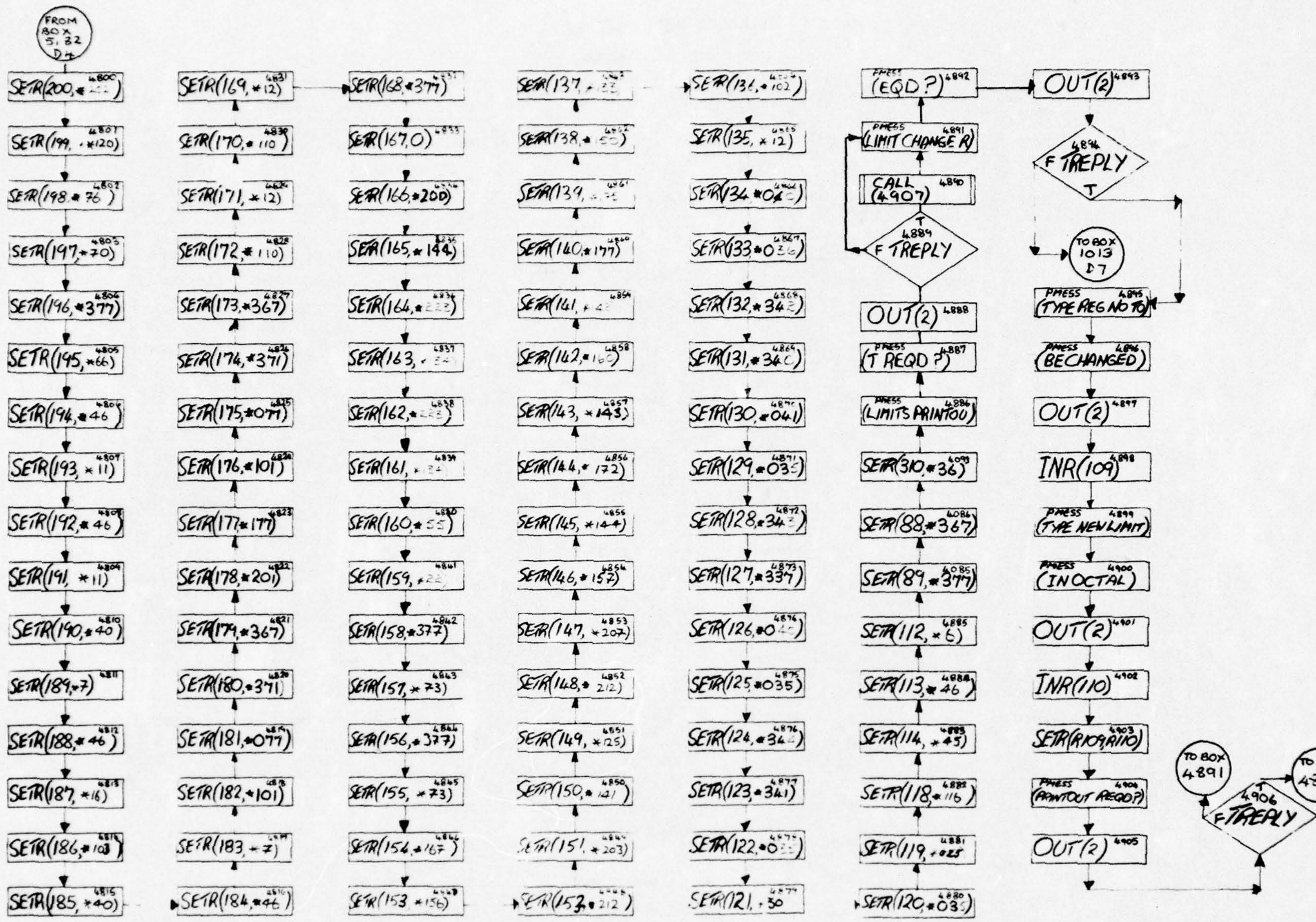
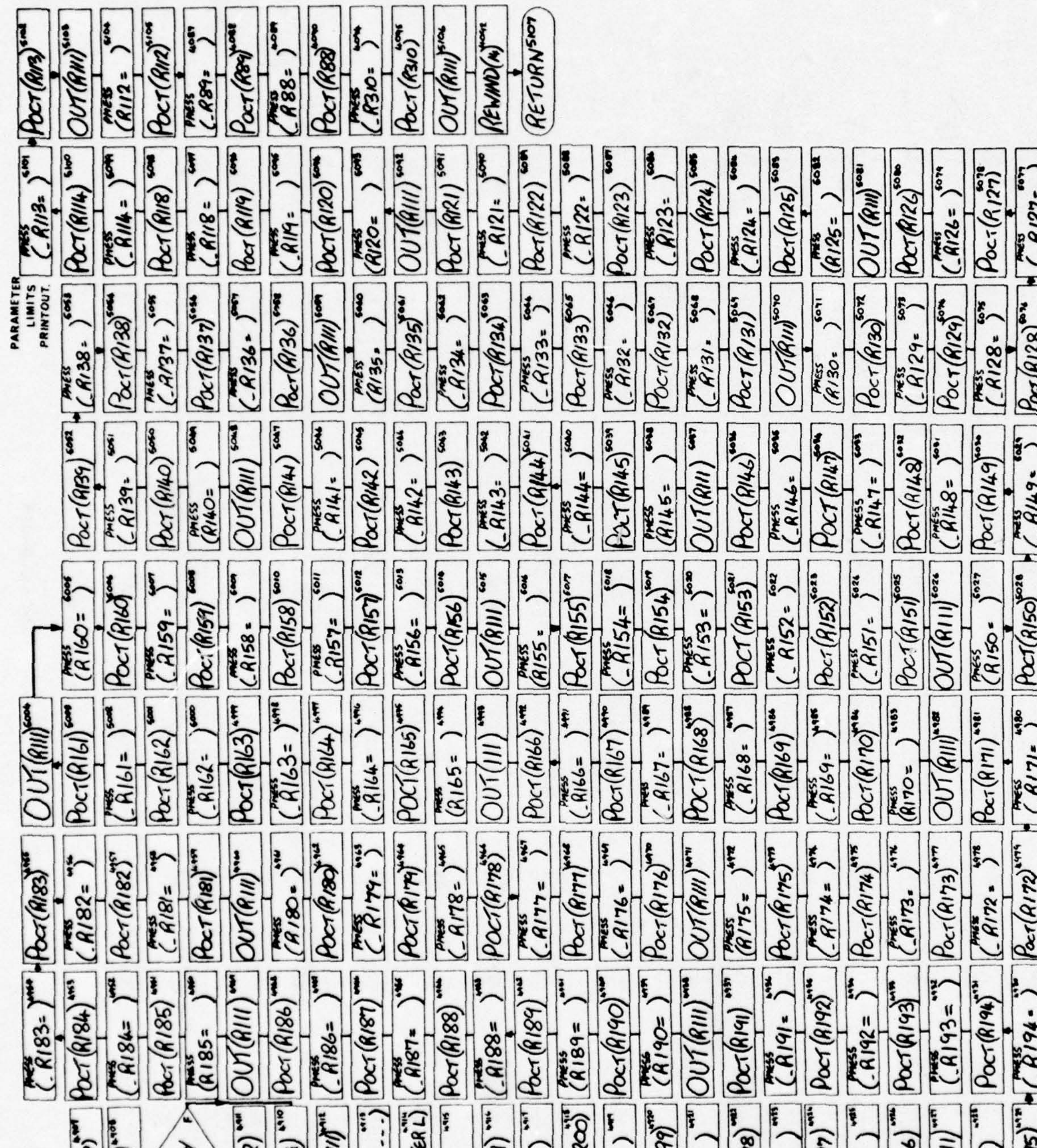


Parameter limit check and change

Fig.D5 Set up phase

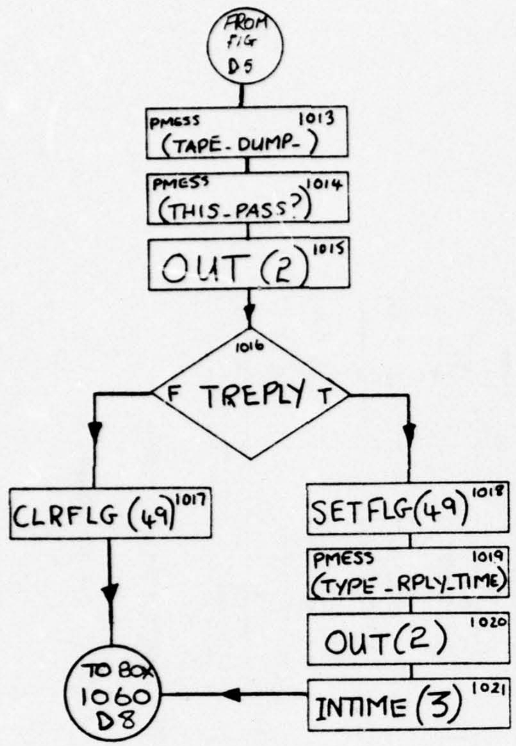
Fig.D5

Fig.D6

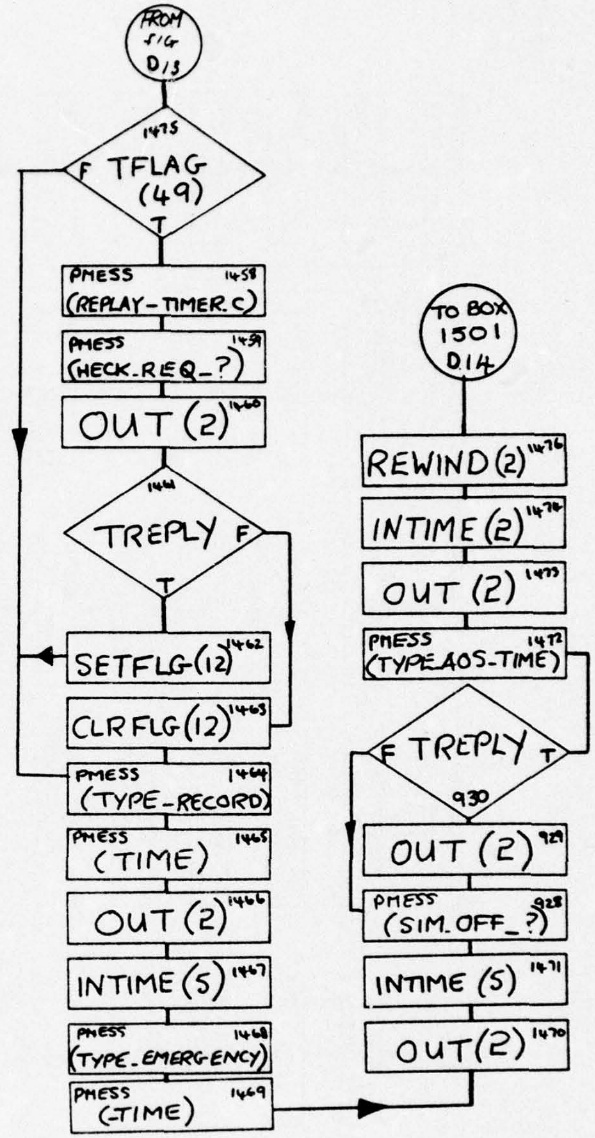


Parameter limits printout

Fig.D6 Set up phase



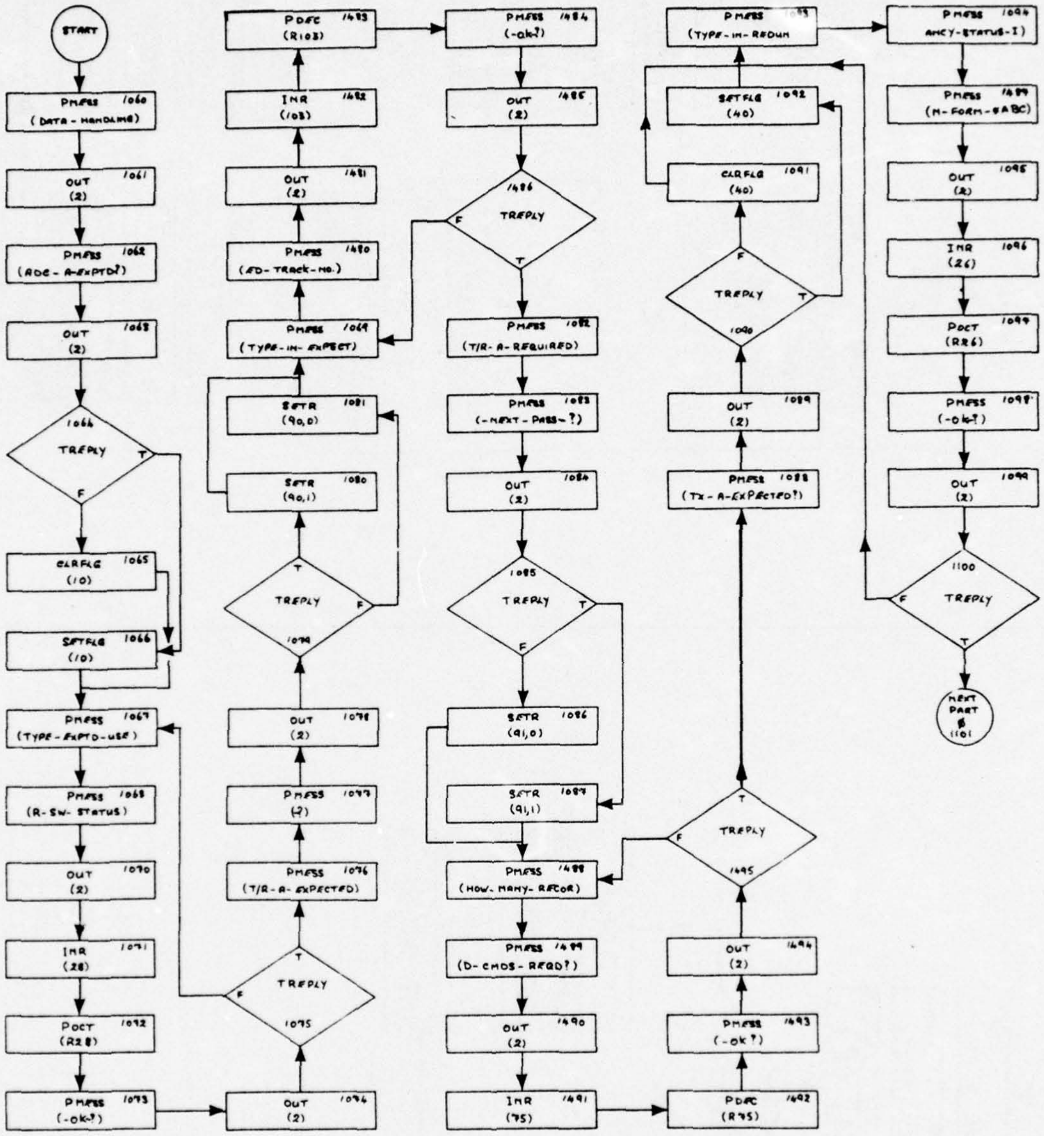
Replay



In time

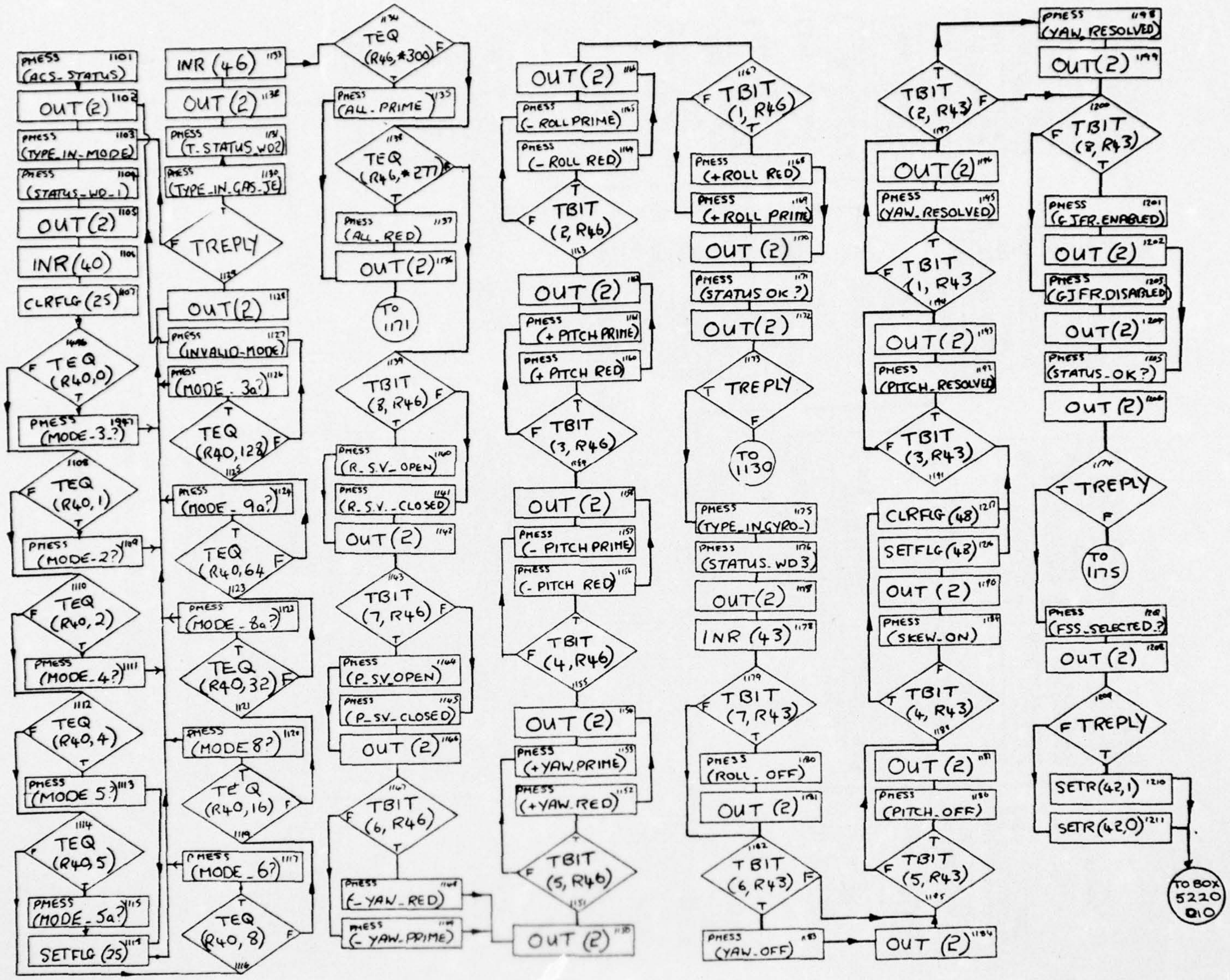
Fig.D7 Set up phase

Fig.D8



Data handling and power supplies

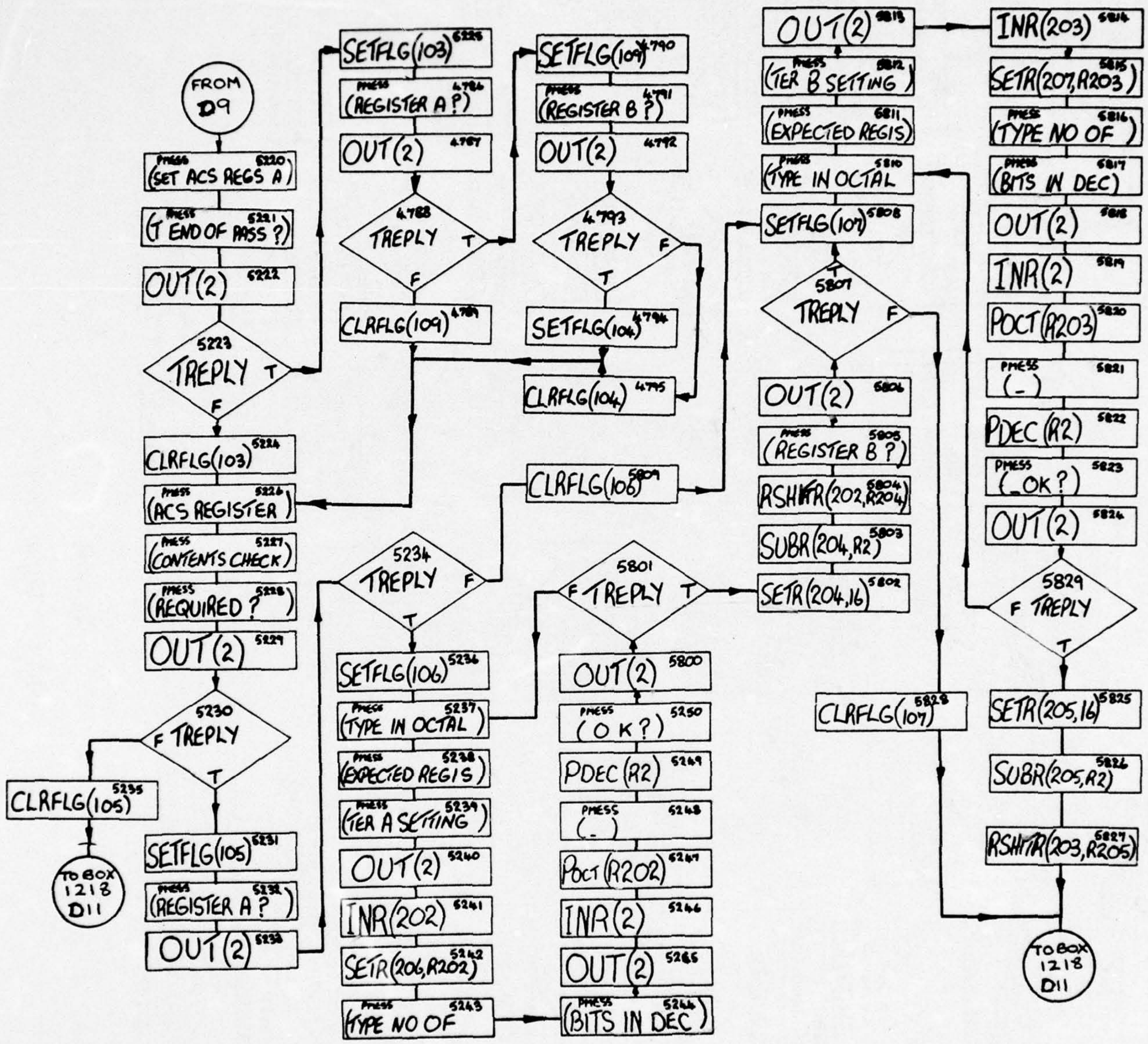
Fig.D8 Set up phase



ACS status

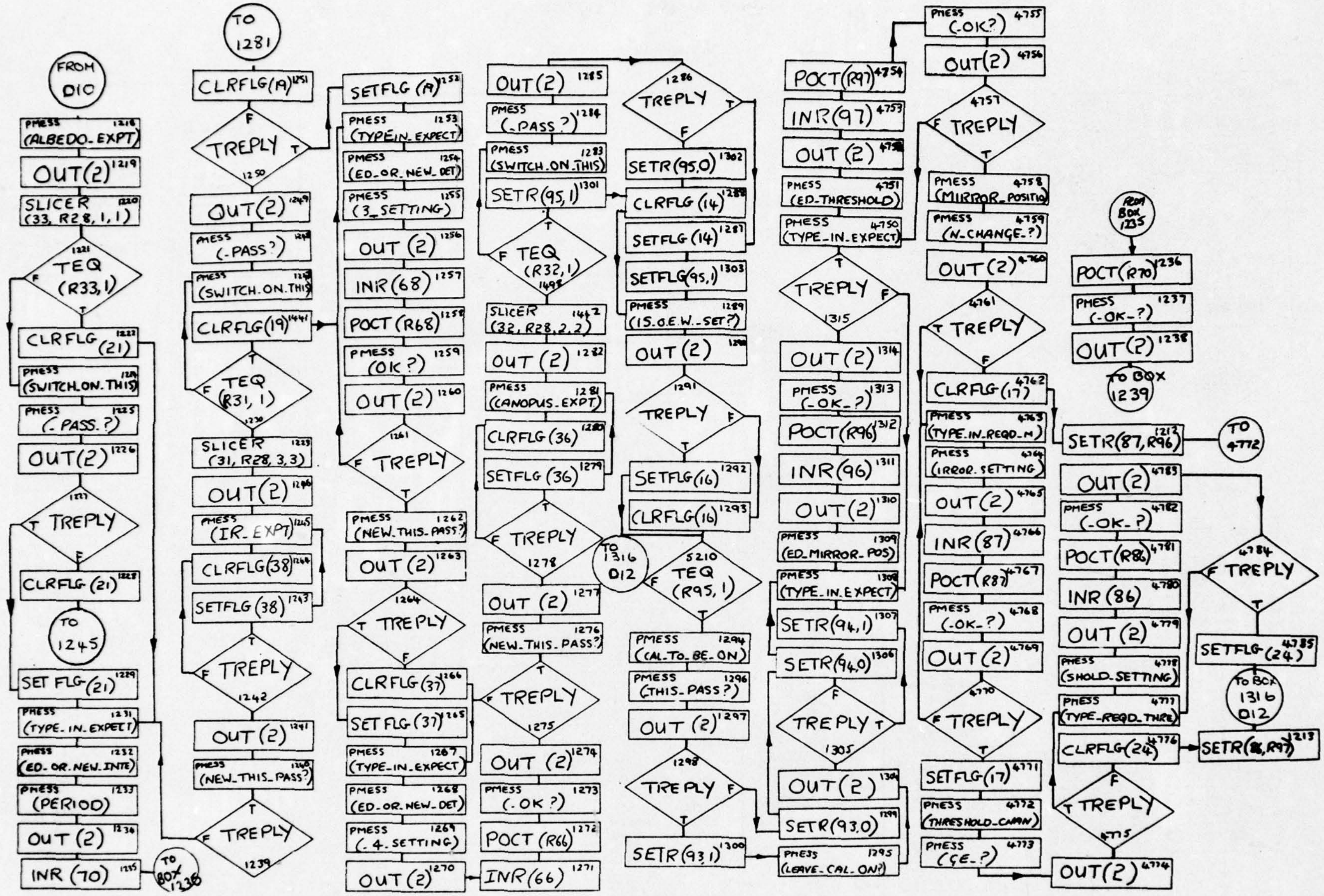
Fig.D9 Set up phase

Fig.D10



ACS registers, contents and evaluation

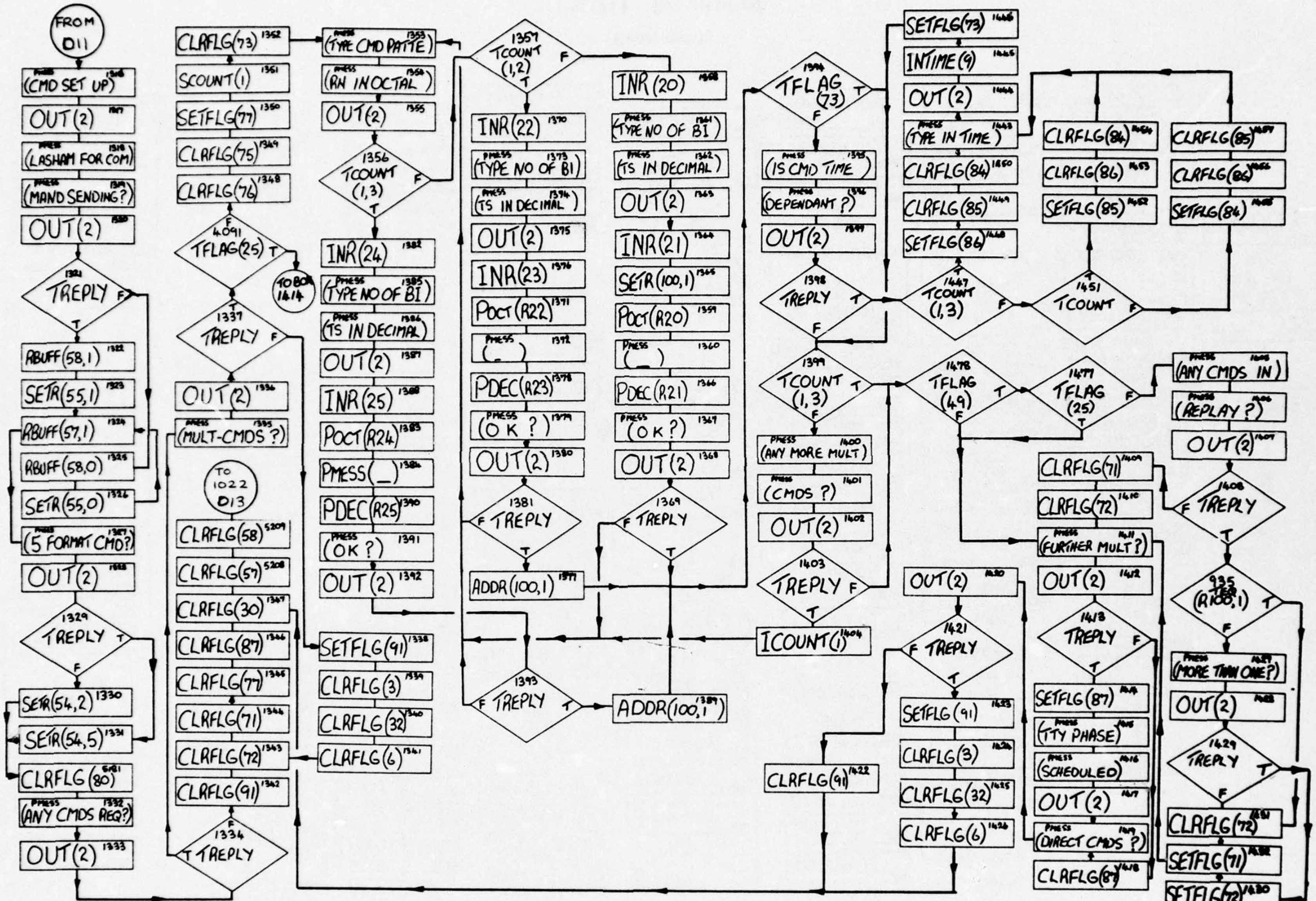
Fig.D10 Set up phase



Experiments

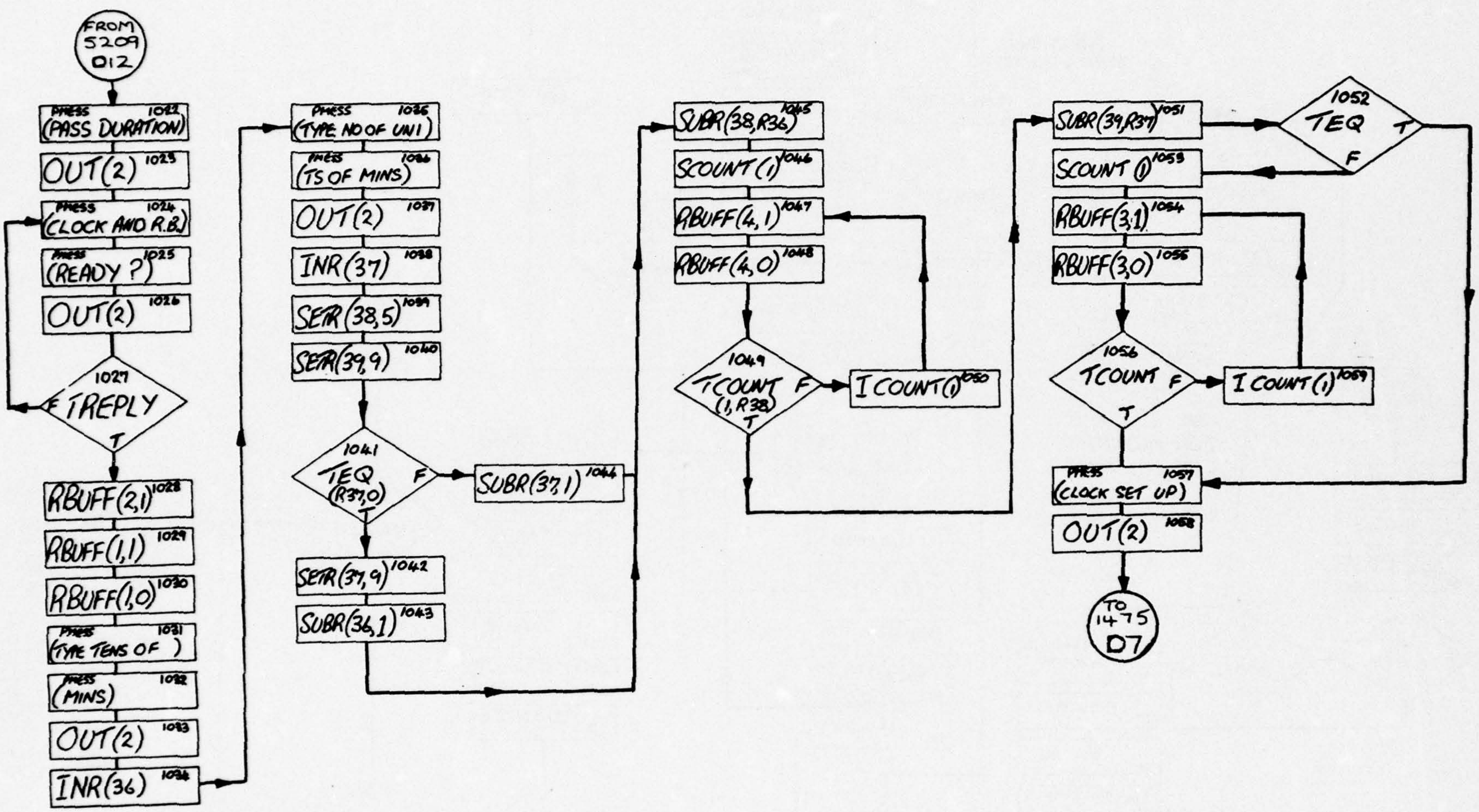
Fig.D11 Set up phase

Fig.D12



Commands

Fig.D12 Set up phase



Countdown clock

Fig.D13 Set up phase

Fig.D13

Fig.D14

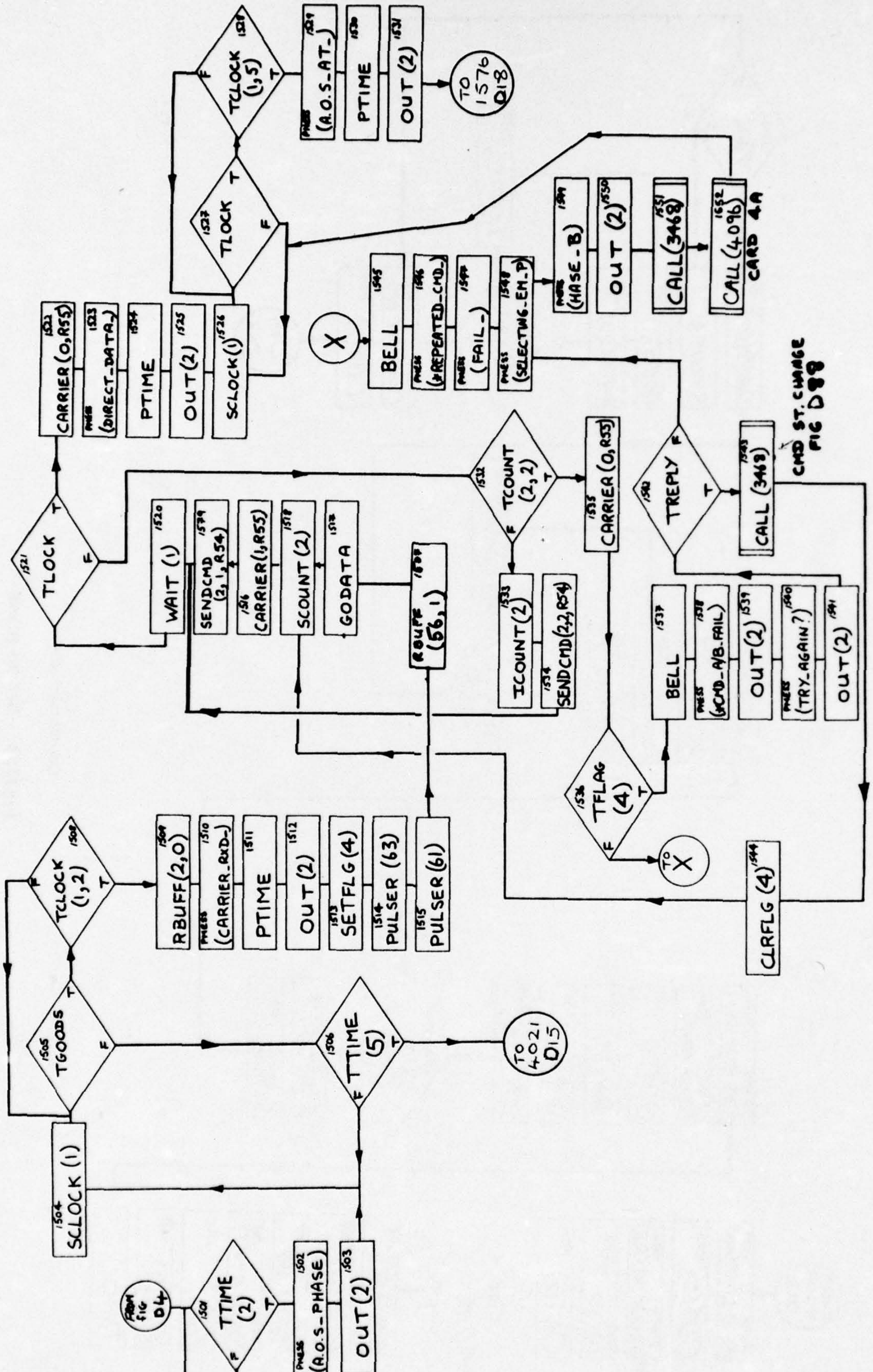
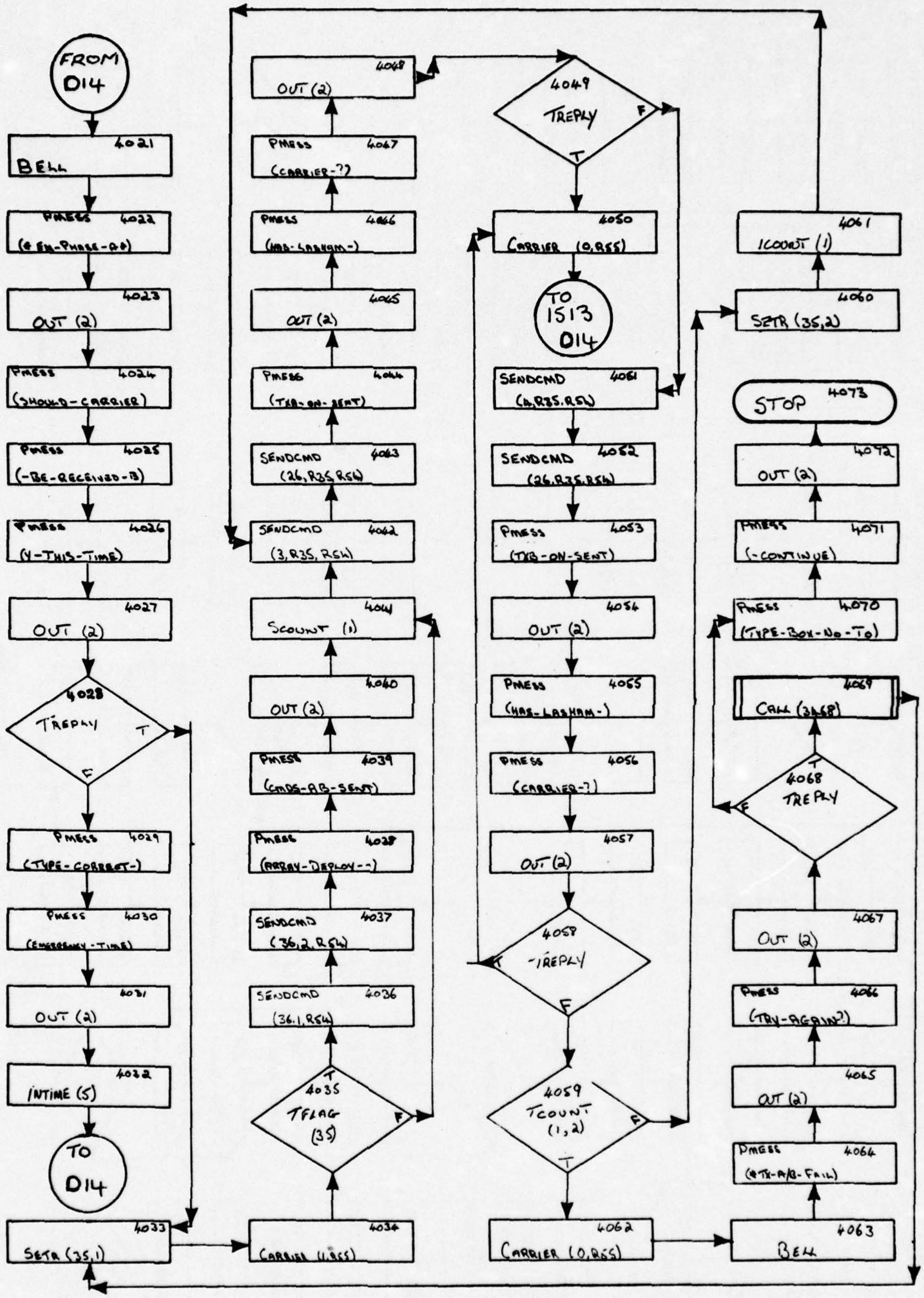


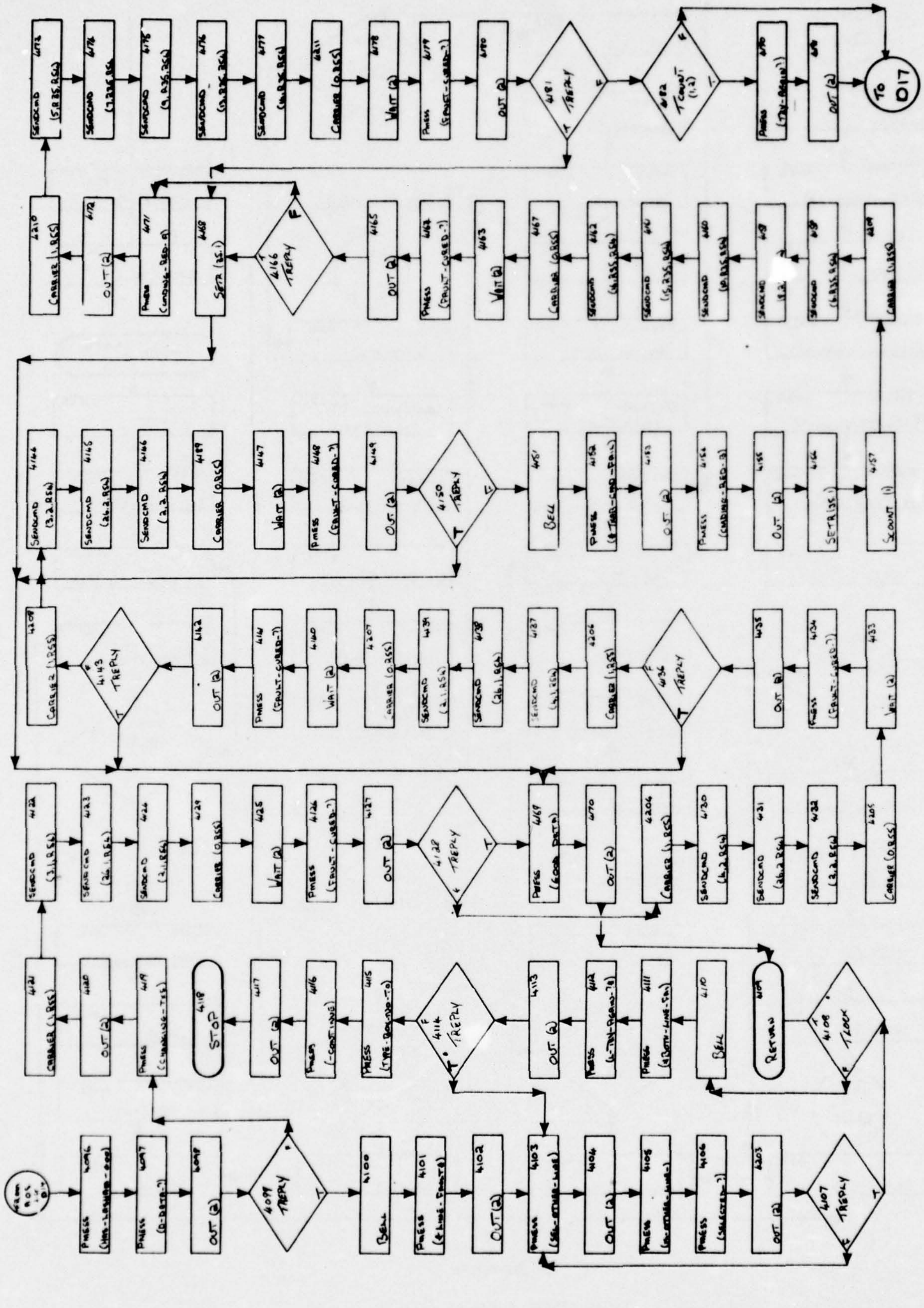
Fig.D14 AOS phase



No carrier

Fig.D15 Emergency A

Fig.D16



No modulation

Fig.D16 Emergency B

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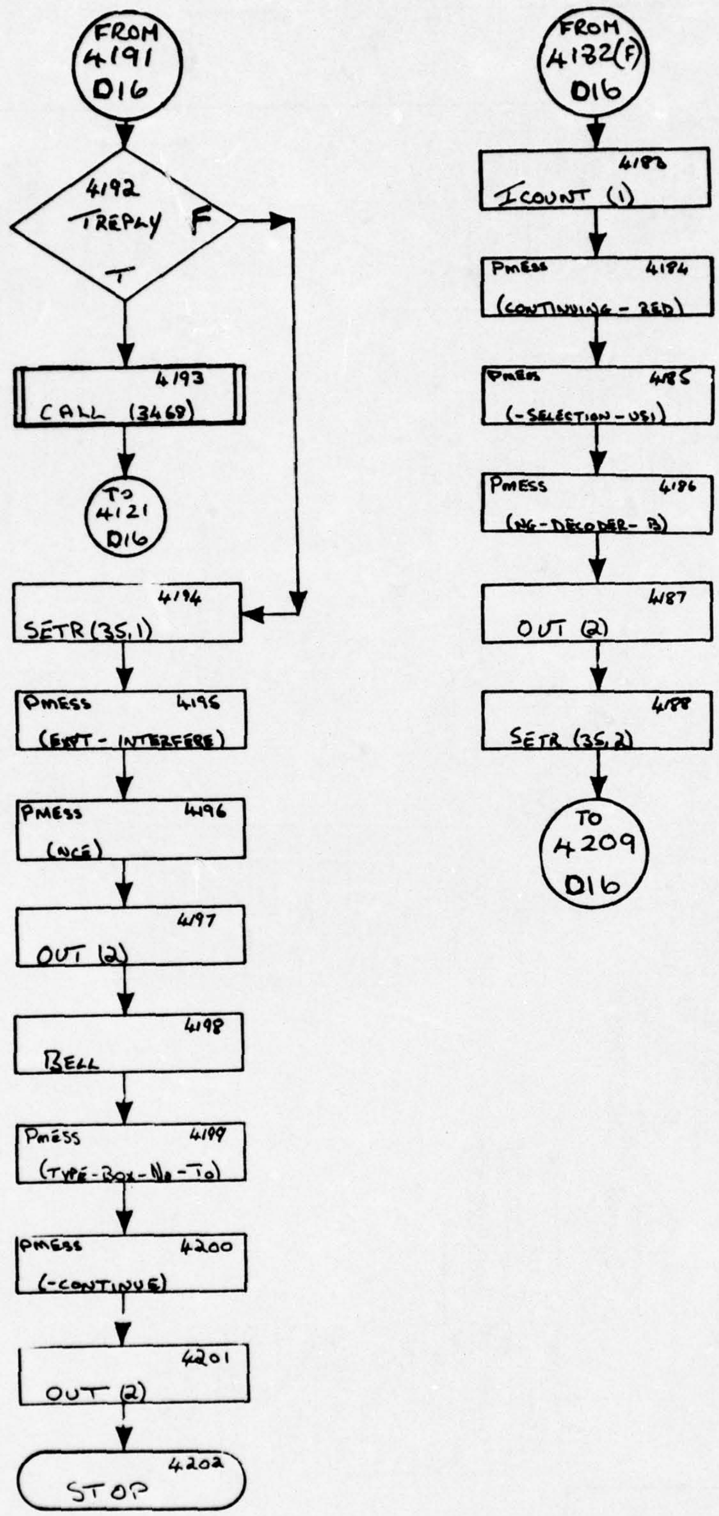


Fig.D17 Emergency B

Fig.D18

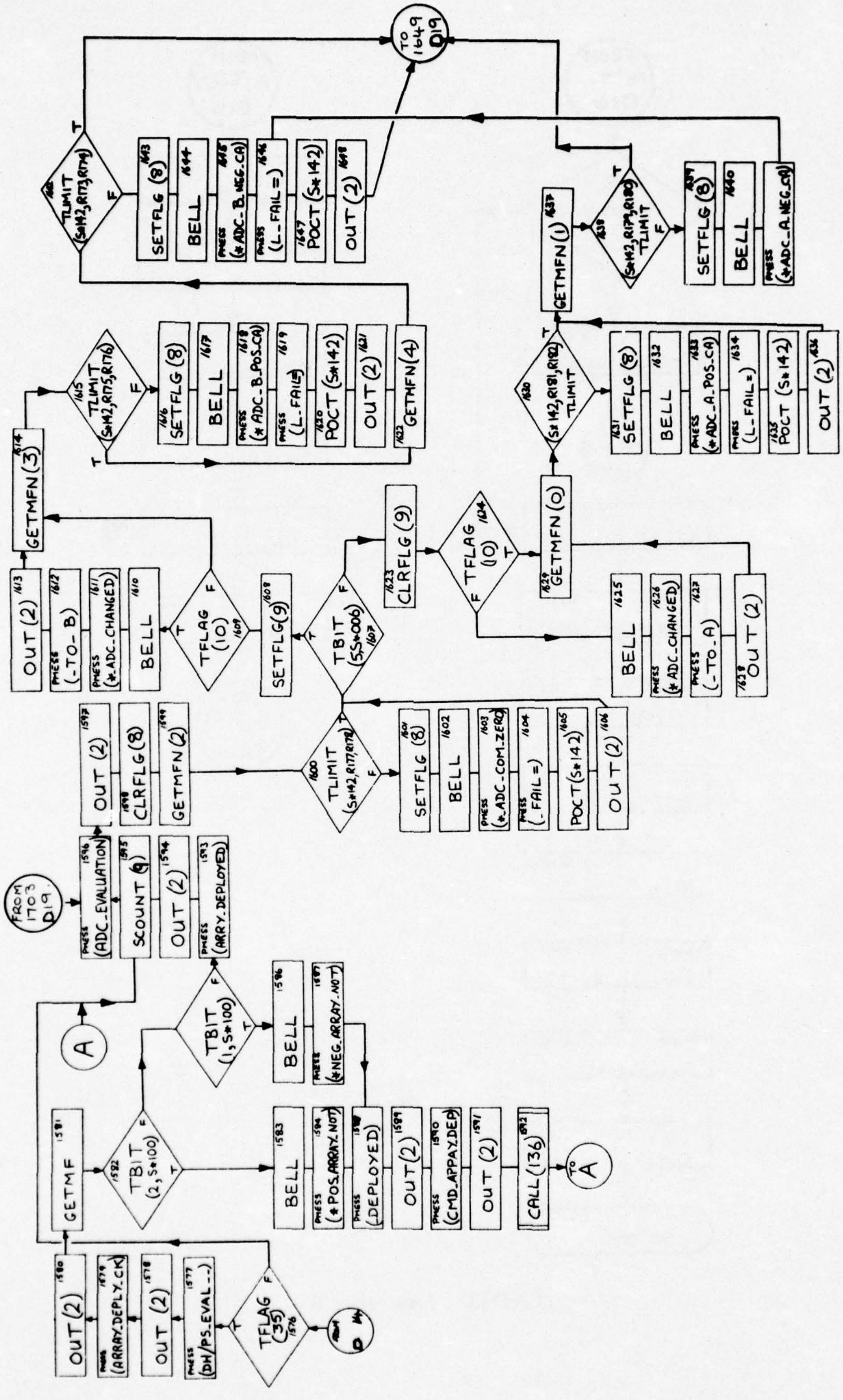


Fig.D18 Data handling and power supply evaluation

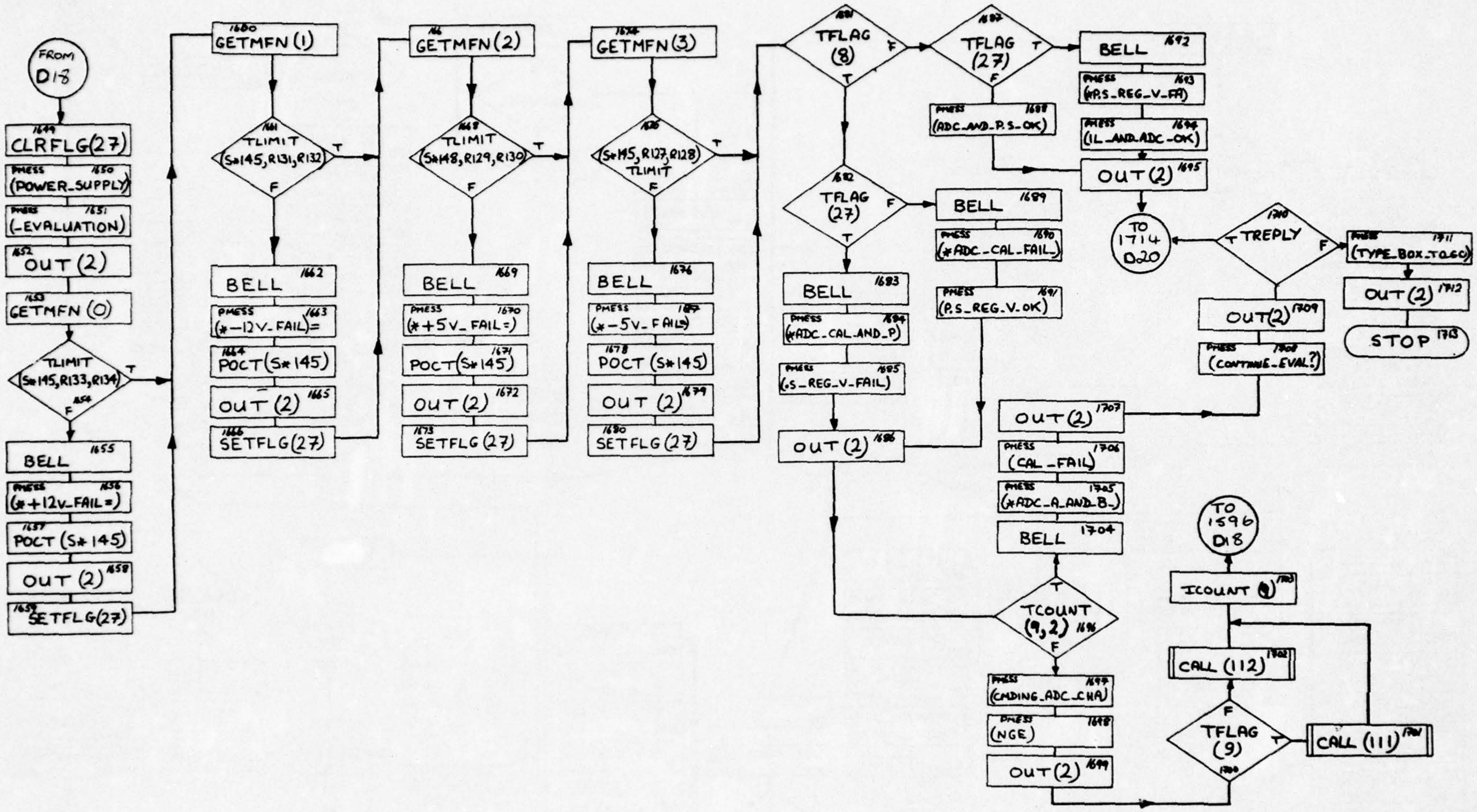


Fig.D19 Data handling and power supply evaluation

Fig.D20

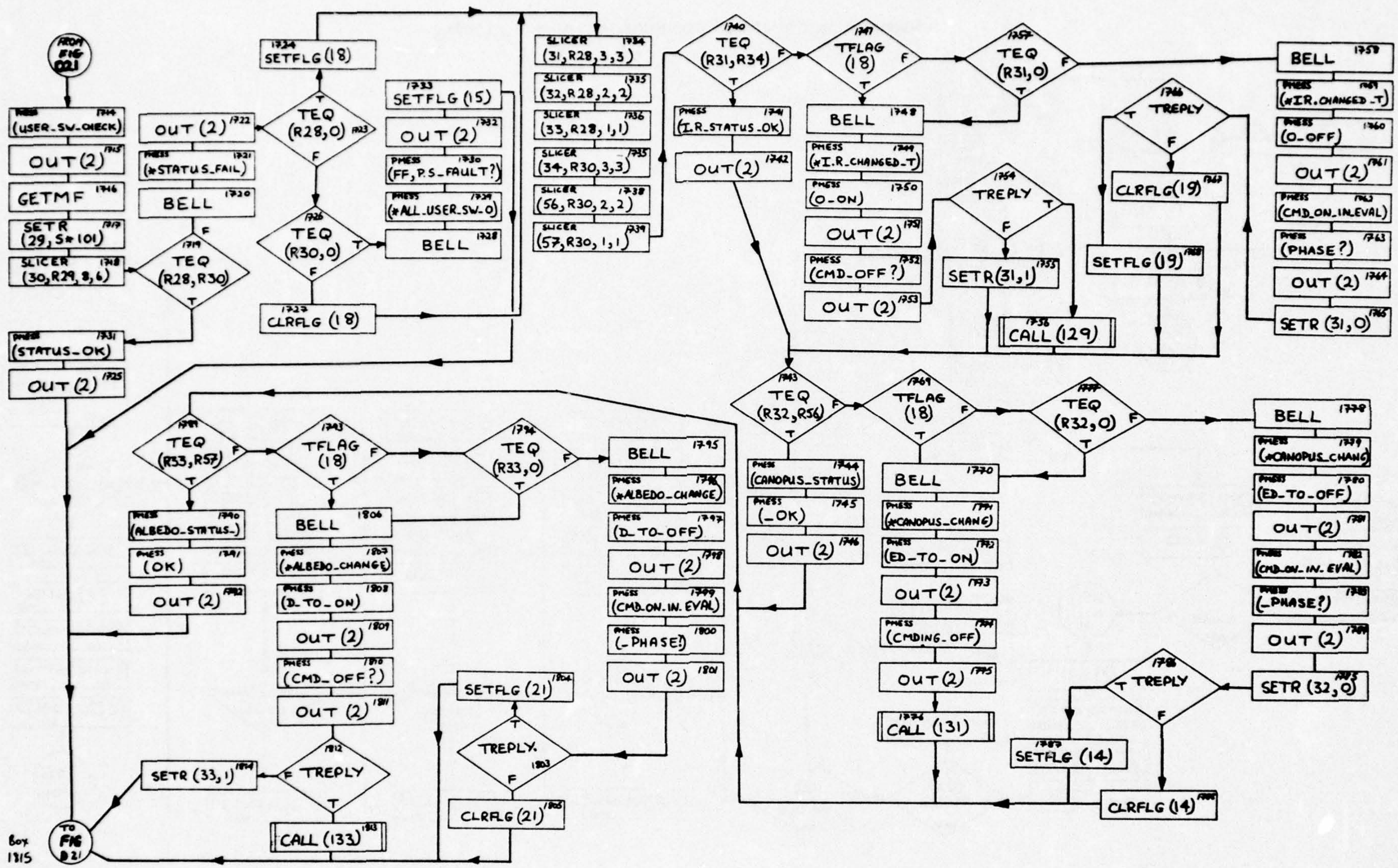


Fig.D20 Data handling and power supply evaluation

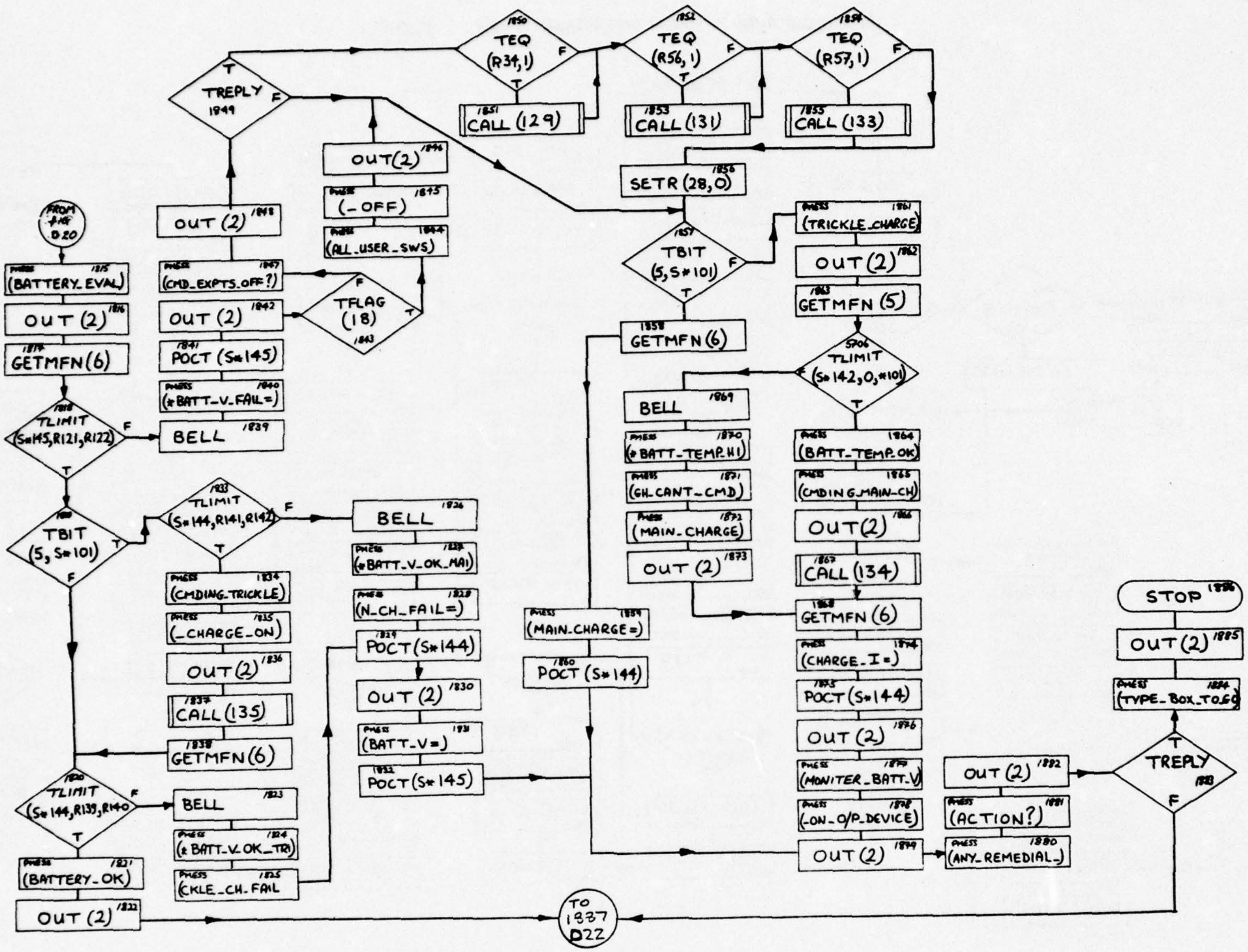


Fig.D21 Data handling and power supply evaluation

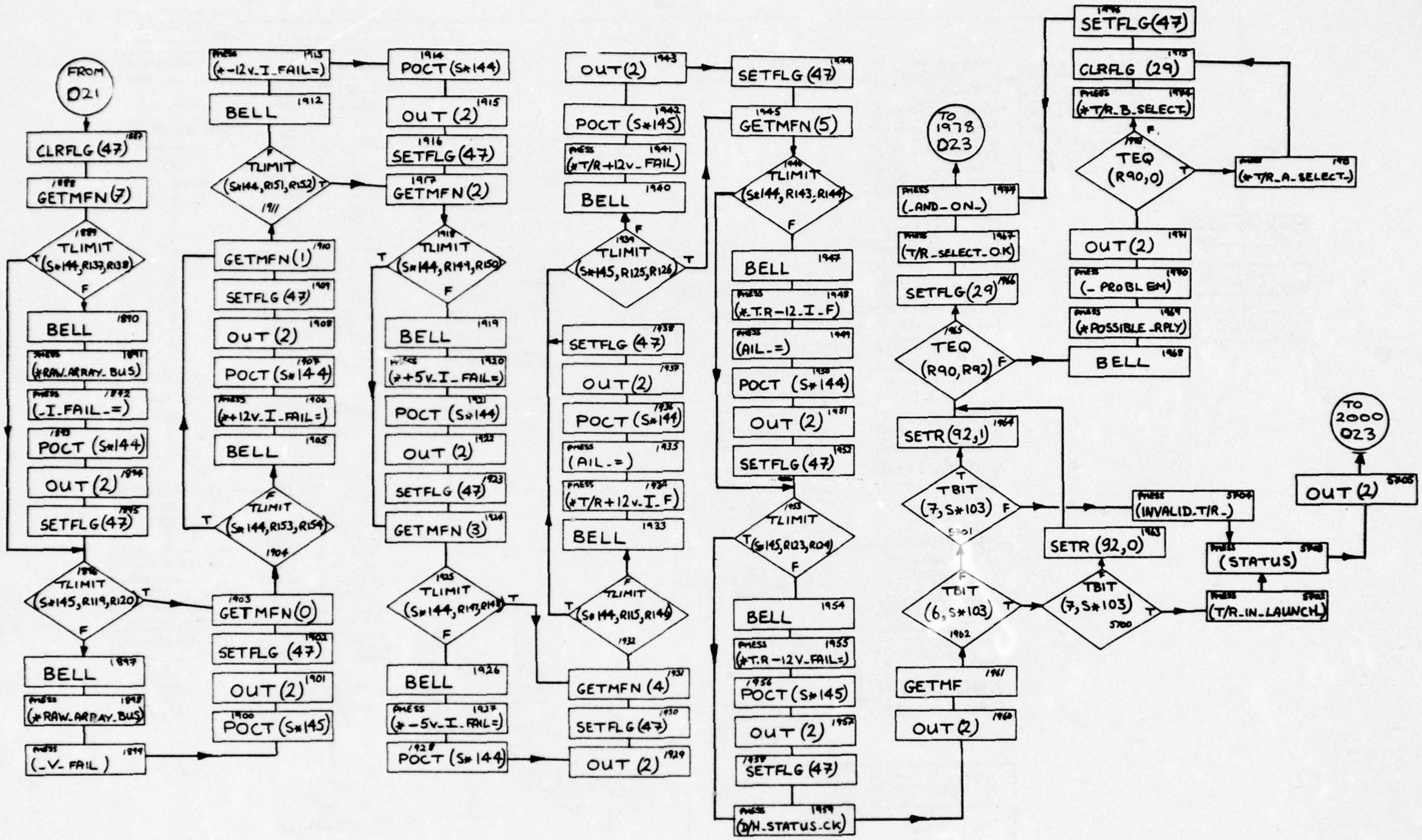


Fig.D22 Data handling and power supply evaluation

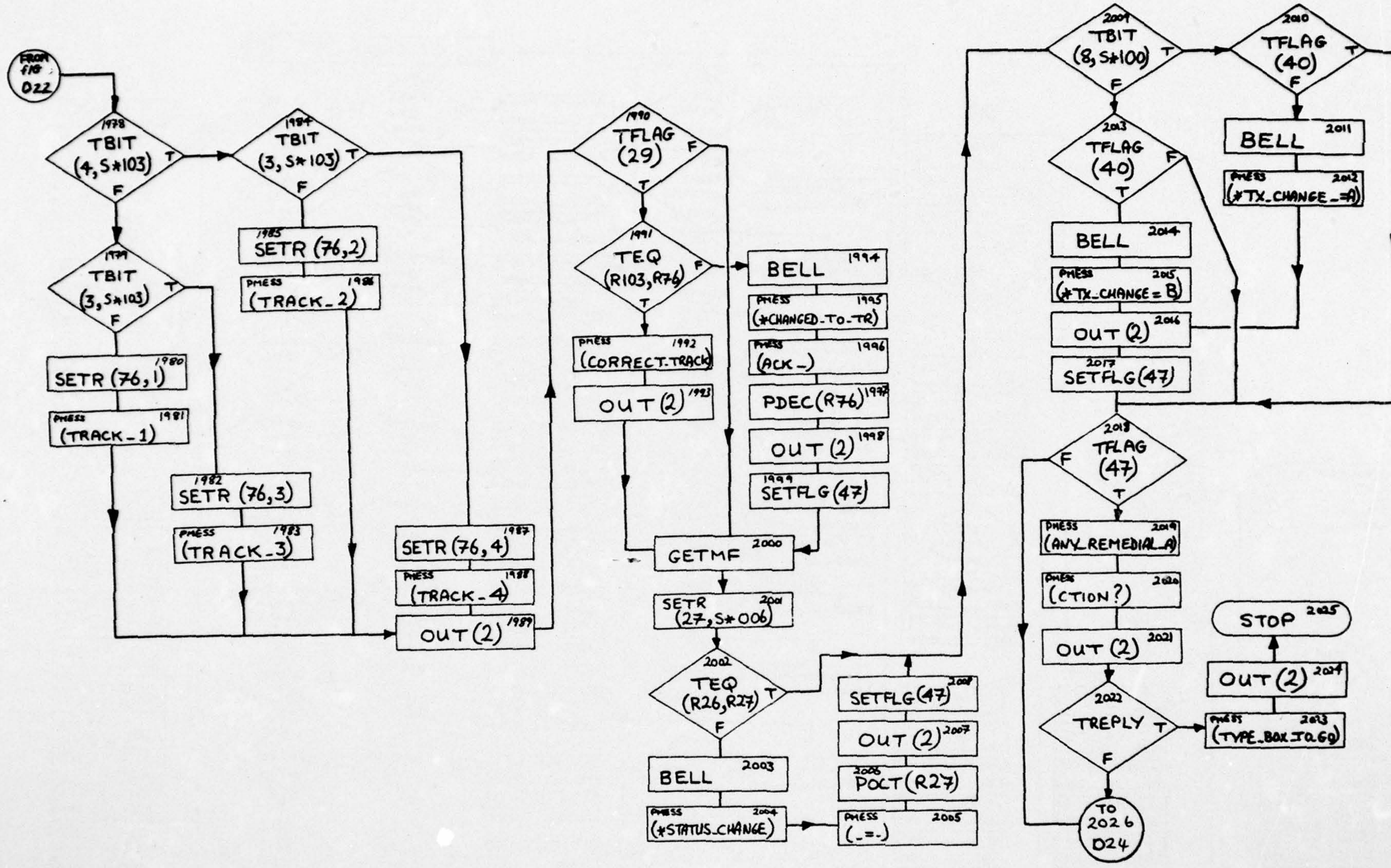


Fig.D23 Data handling and power supply evaluation

Fig.D23

Fig.D24

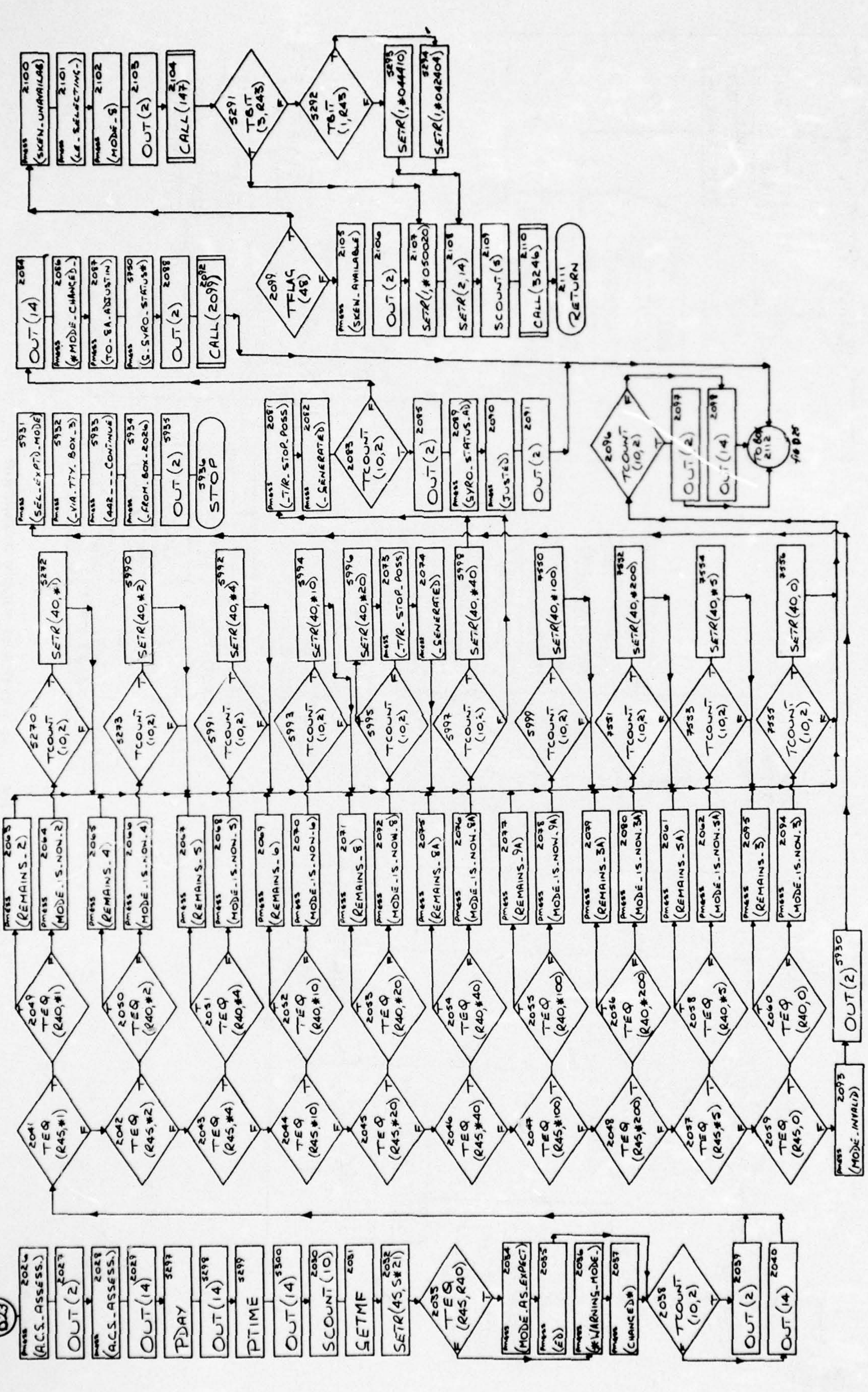
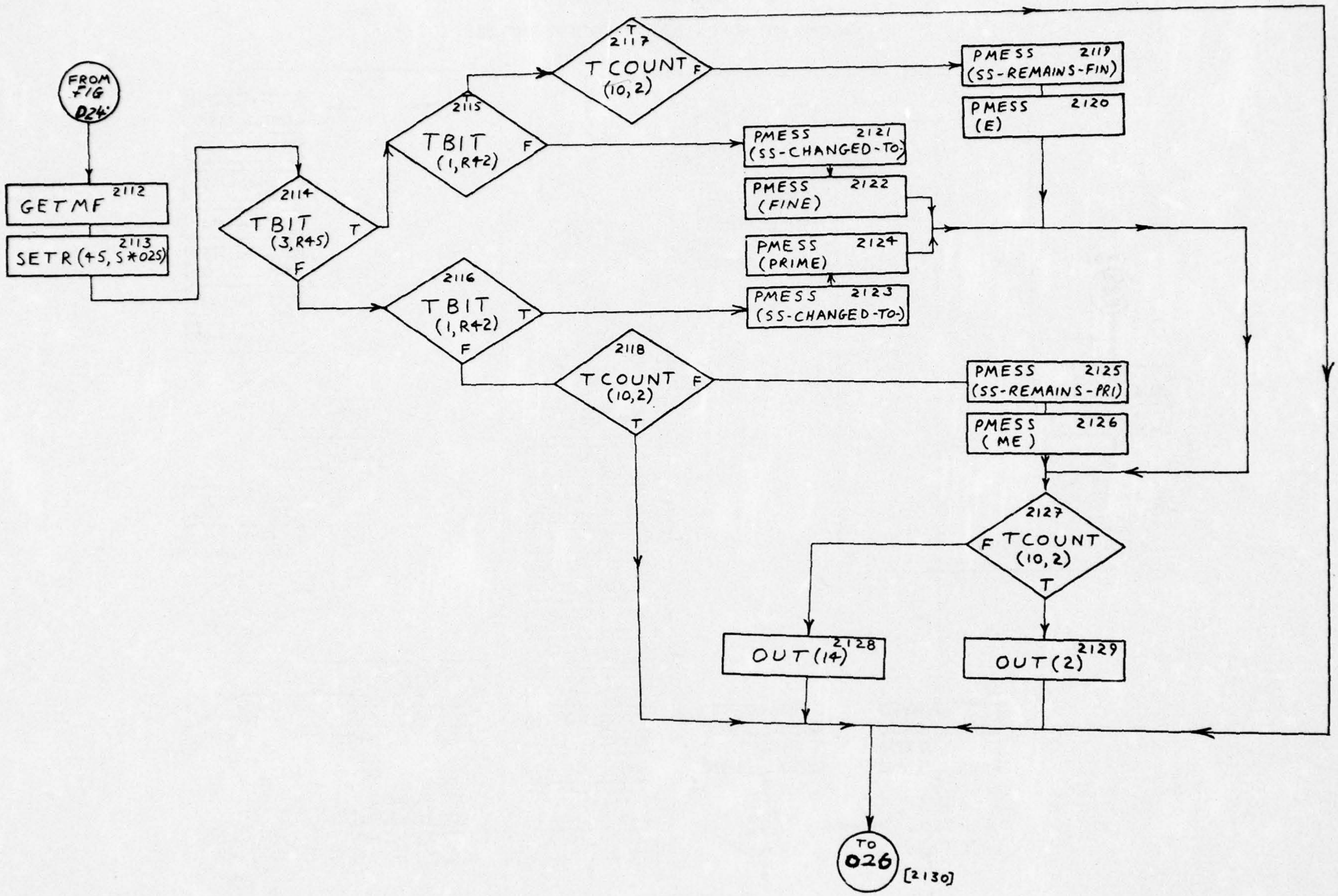


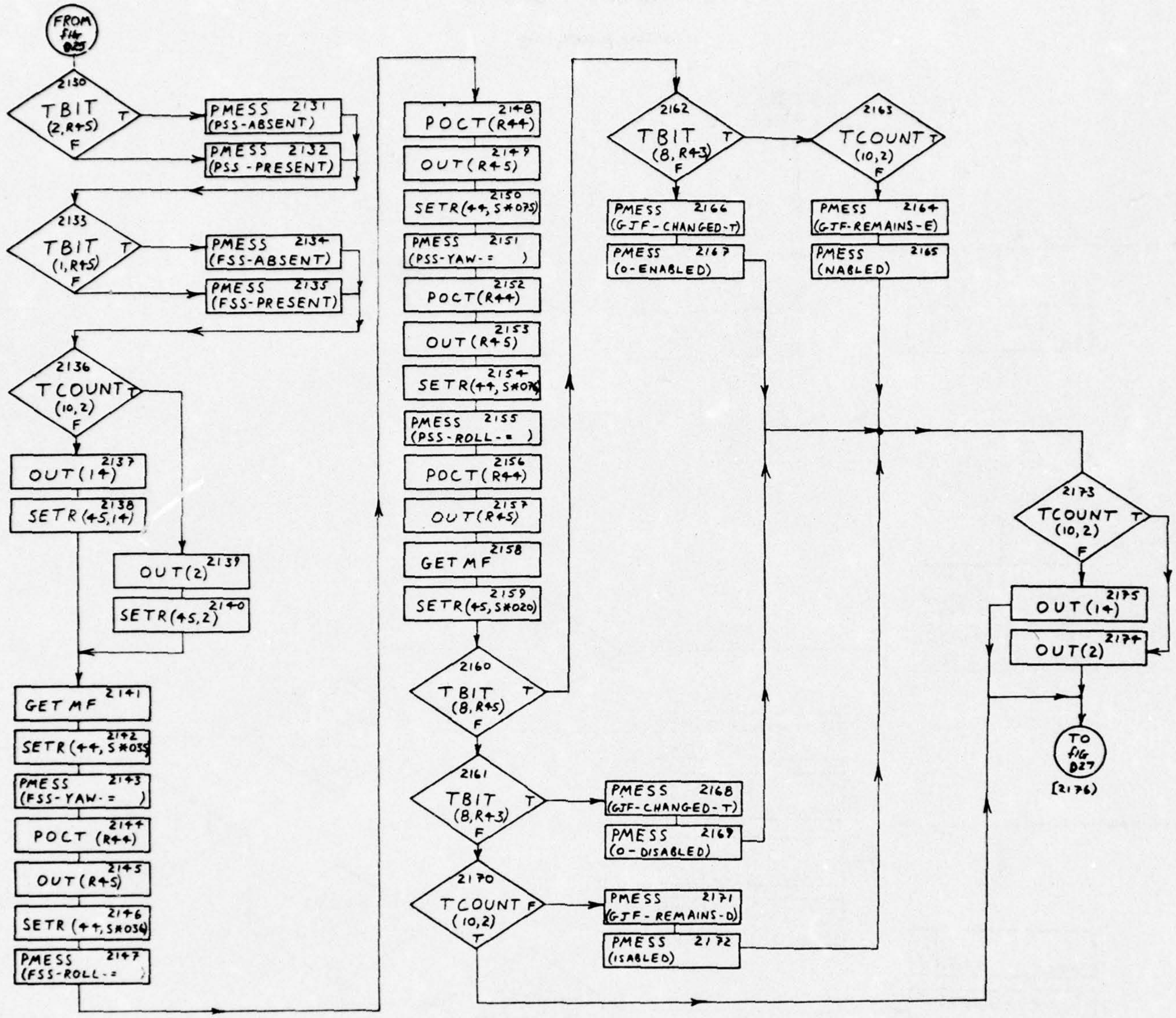
Fig.D24 ACS Phase 1

Mode check



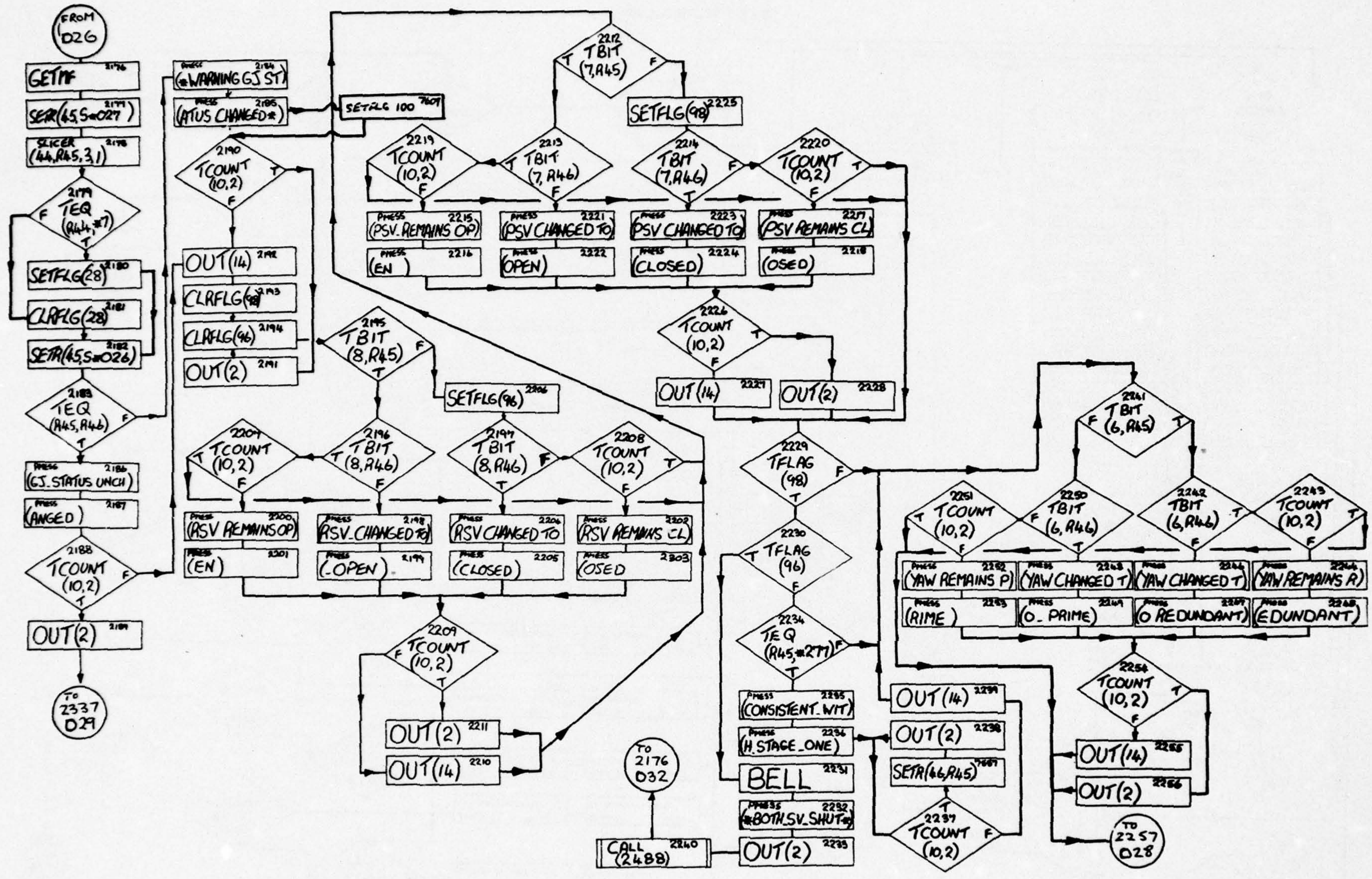
Sun sensor status

Fig.D25 ACS Phase 1



SS presence –PSS and FSS O/P, and GJF routine

Fig.D26 ACS Phase 1

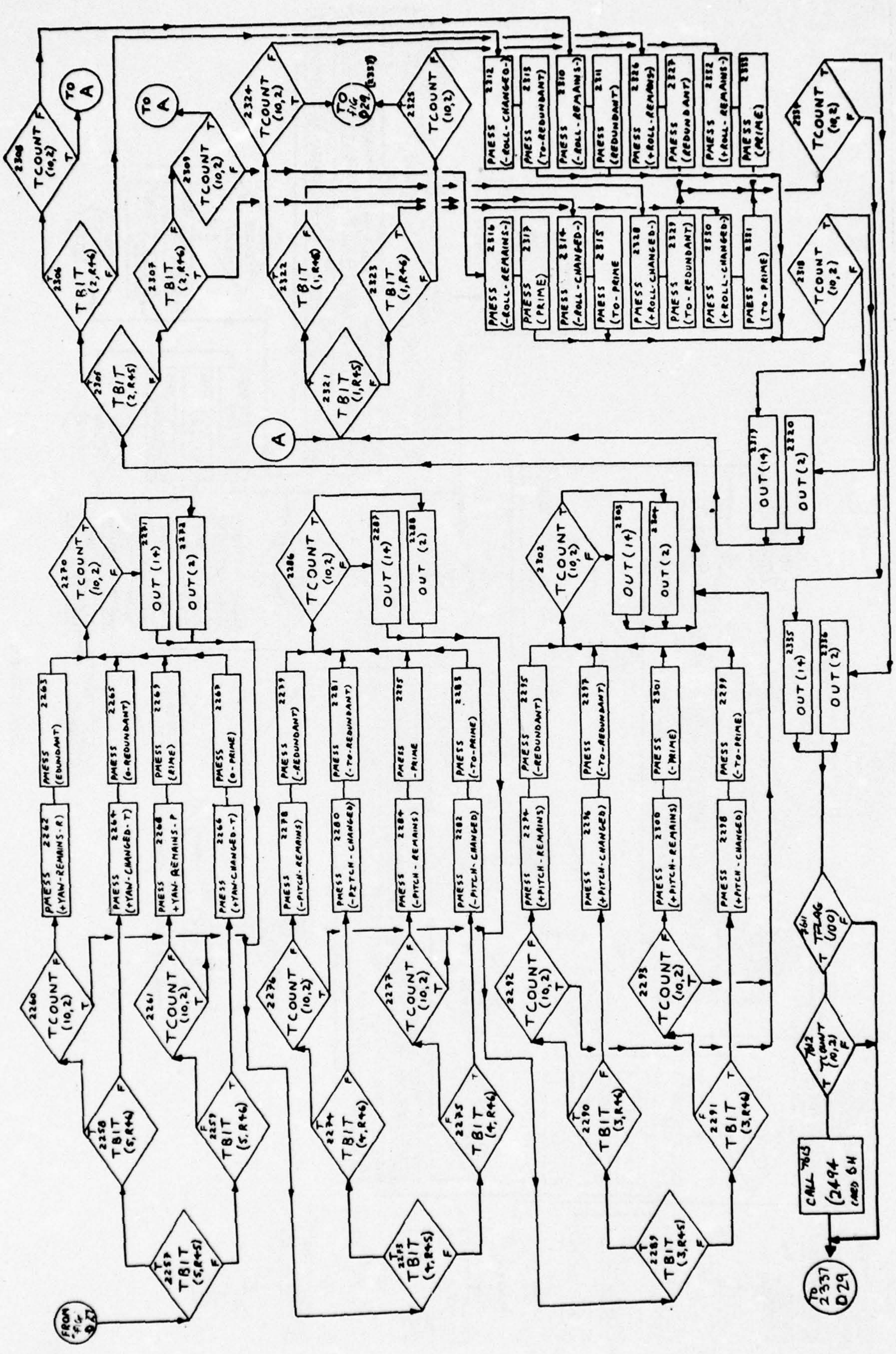


Gas jet status

Fig.D27 ACS Phase 1

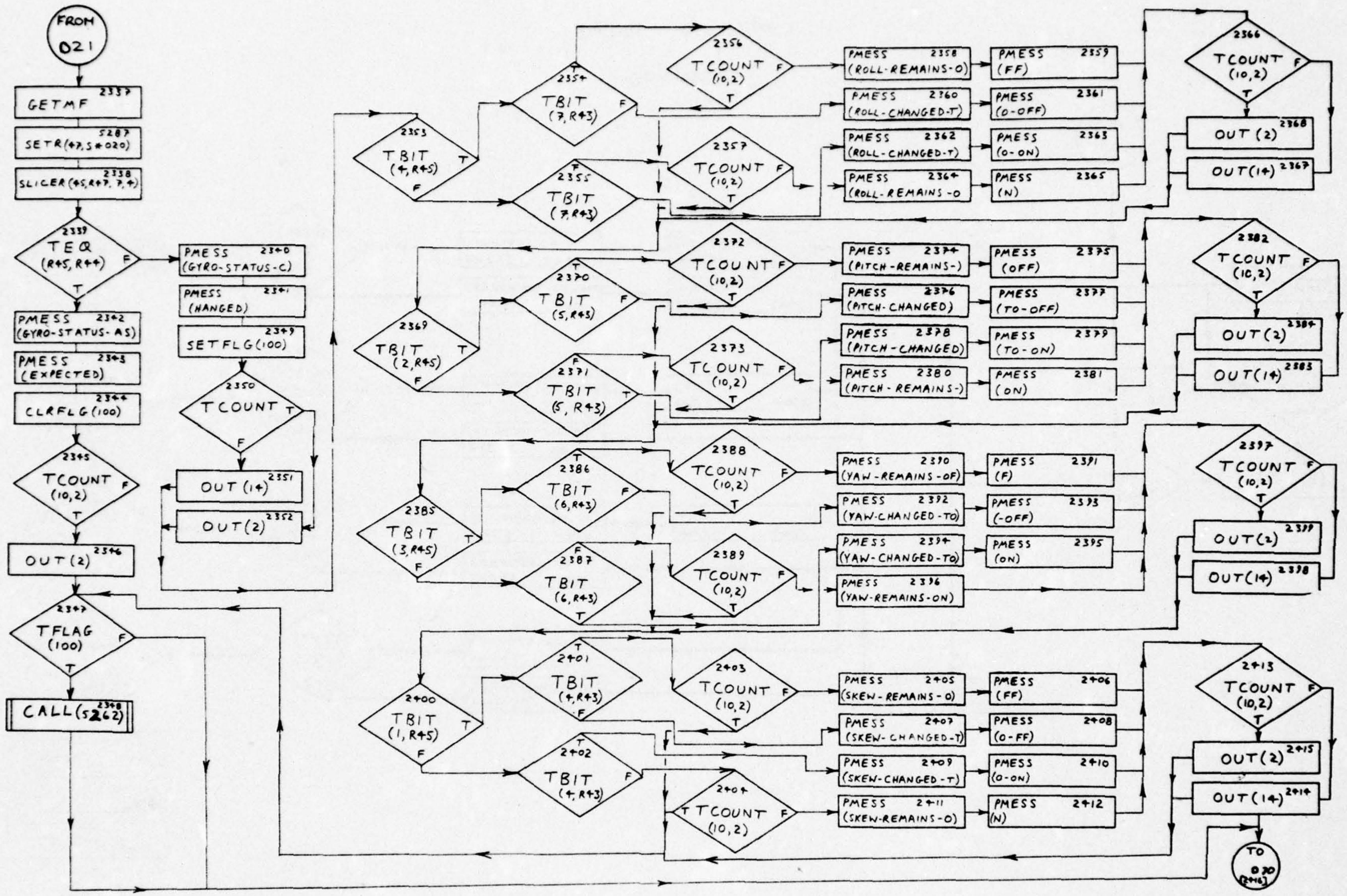
Fig.D27

Fig.D28



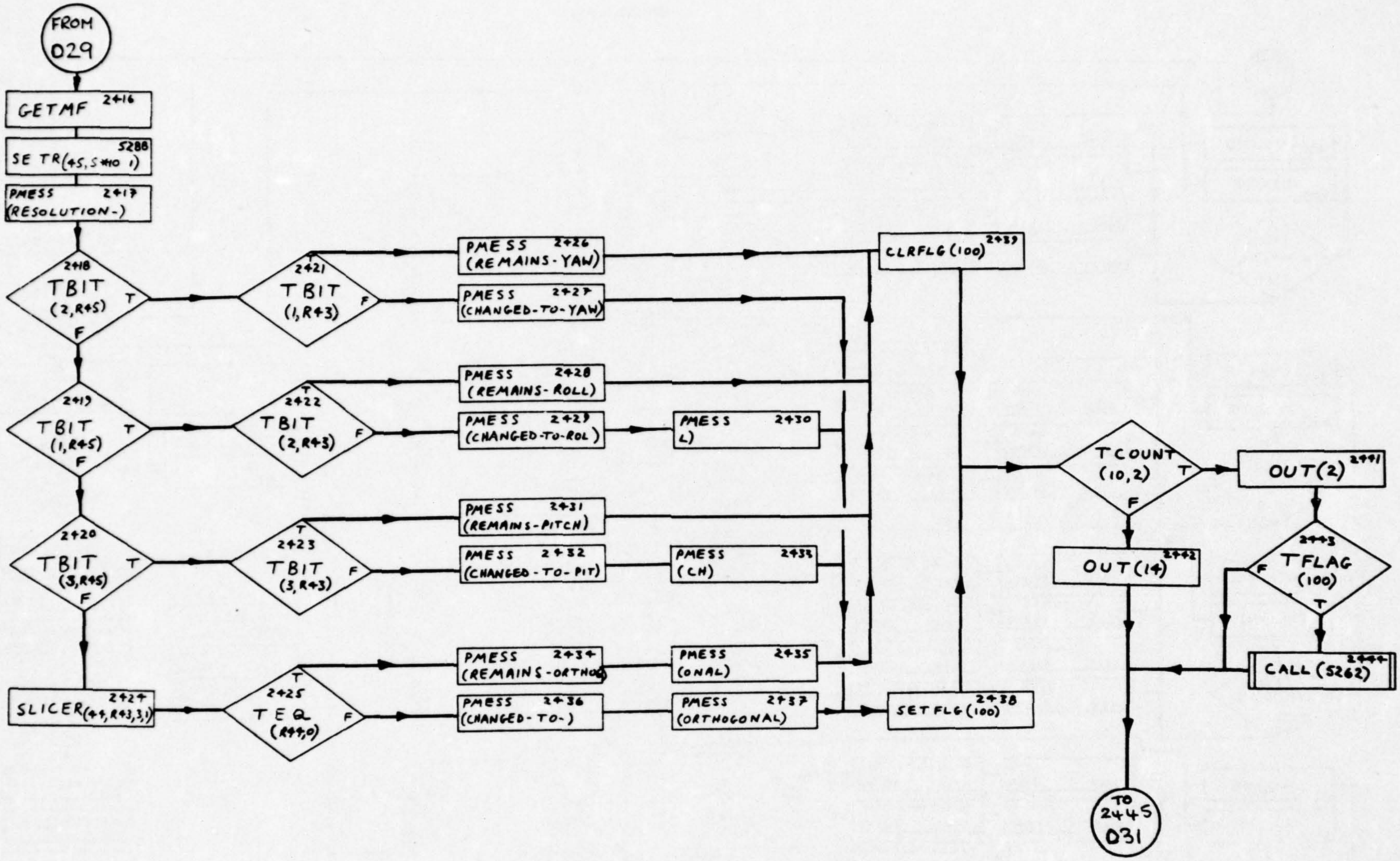
Gas jet status contd.

Fig.D28 ACS Phase 1



Gyro status

Fig.D29 ACS Phase 1



Gyro resolution

Fig.D30 ACS Phase 1

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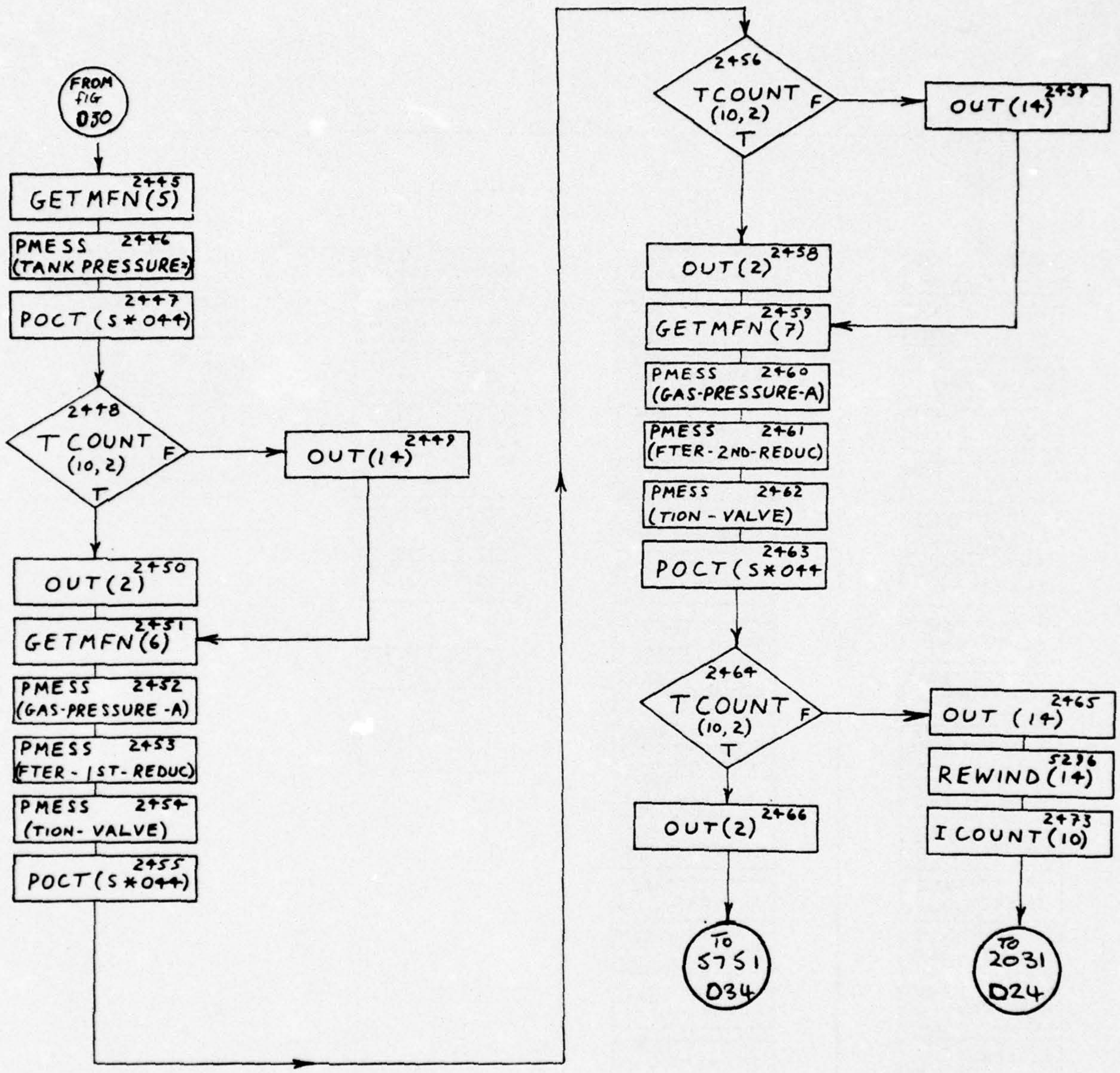
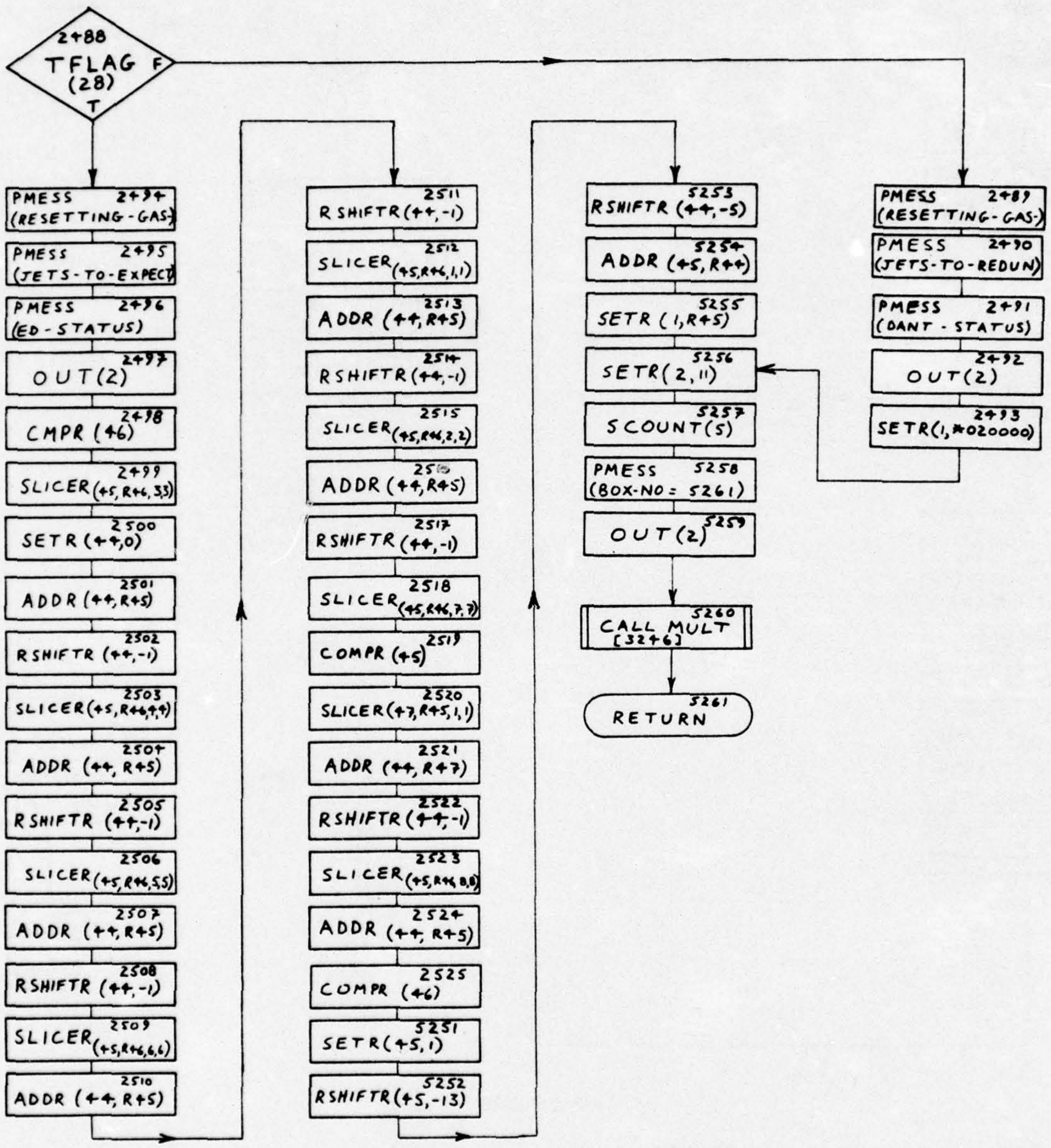


Tank gas pressure

Fig.D31 ACS assessment Phase 1

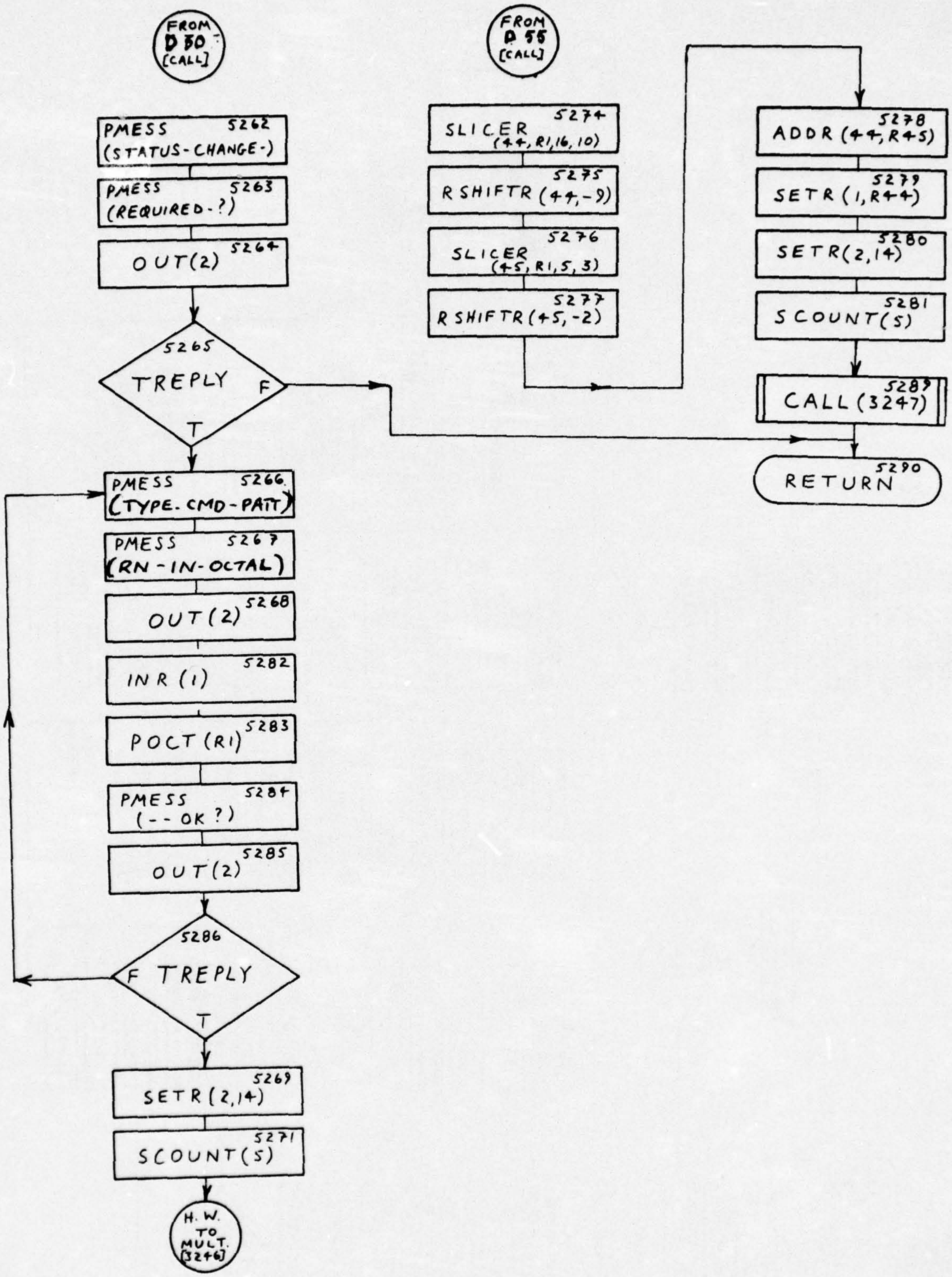
Fig.D32



GJS remedial action if both SV closed

Fig.D32 ACS Phase 1

TR 76016



Remedial action for gyro status

Fig.D33 ACS Phase 1

Fig.D34

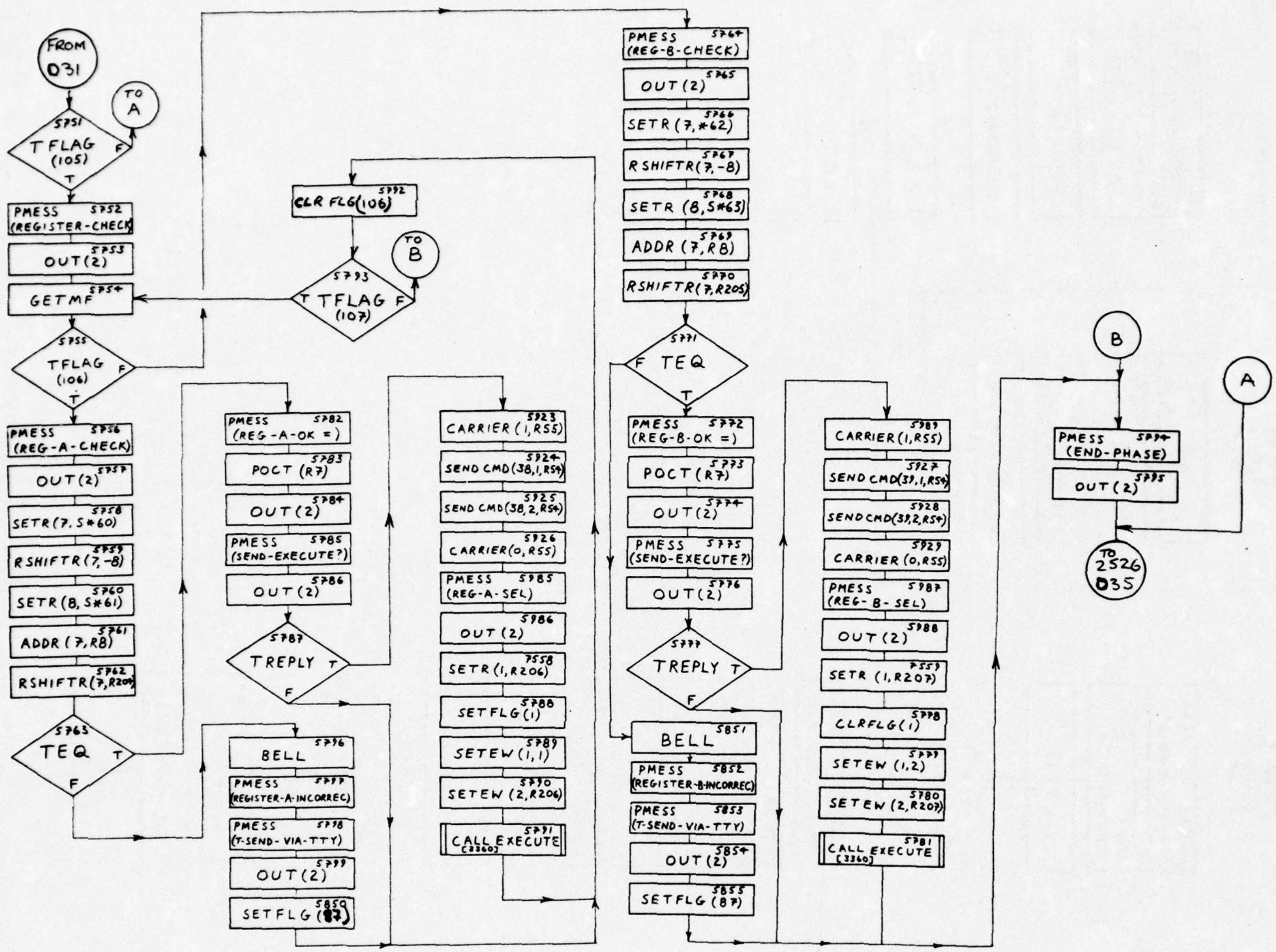


Fig.D34 Examine reg. A and B contents

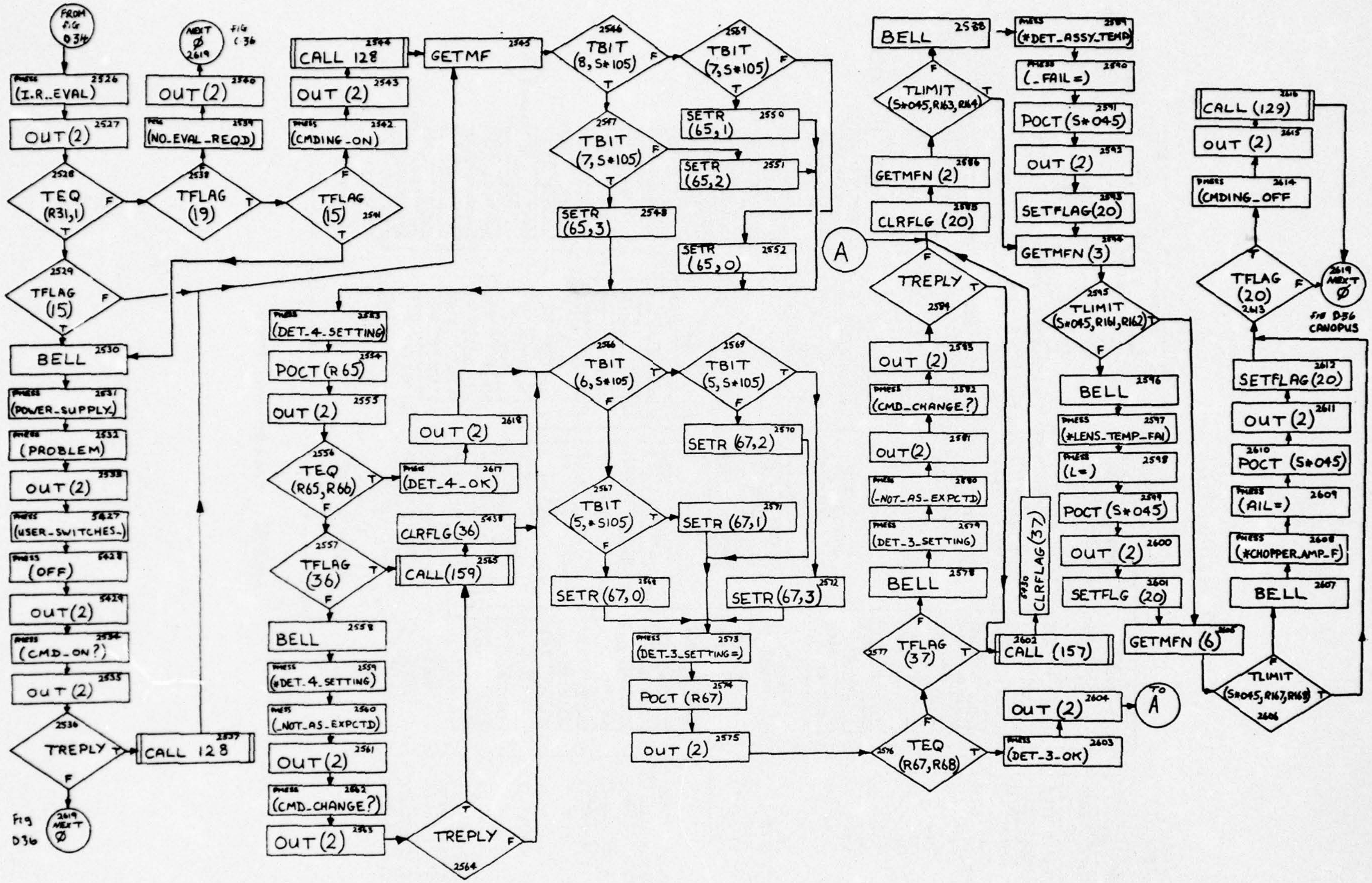


Fig.D35 iR evaluation

Fig.D35

Fig.D36

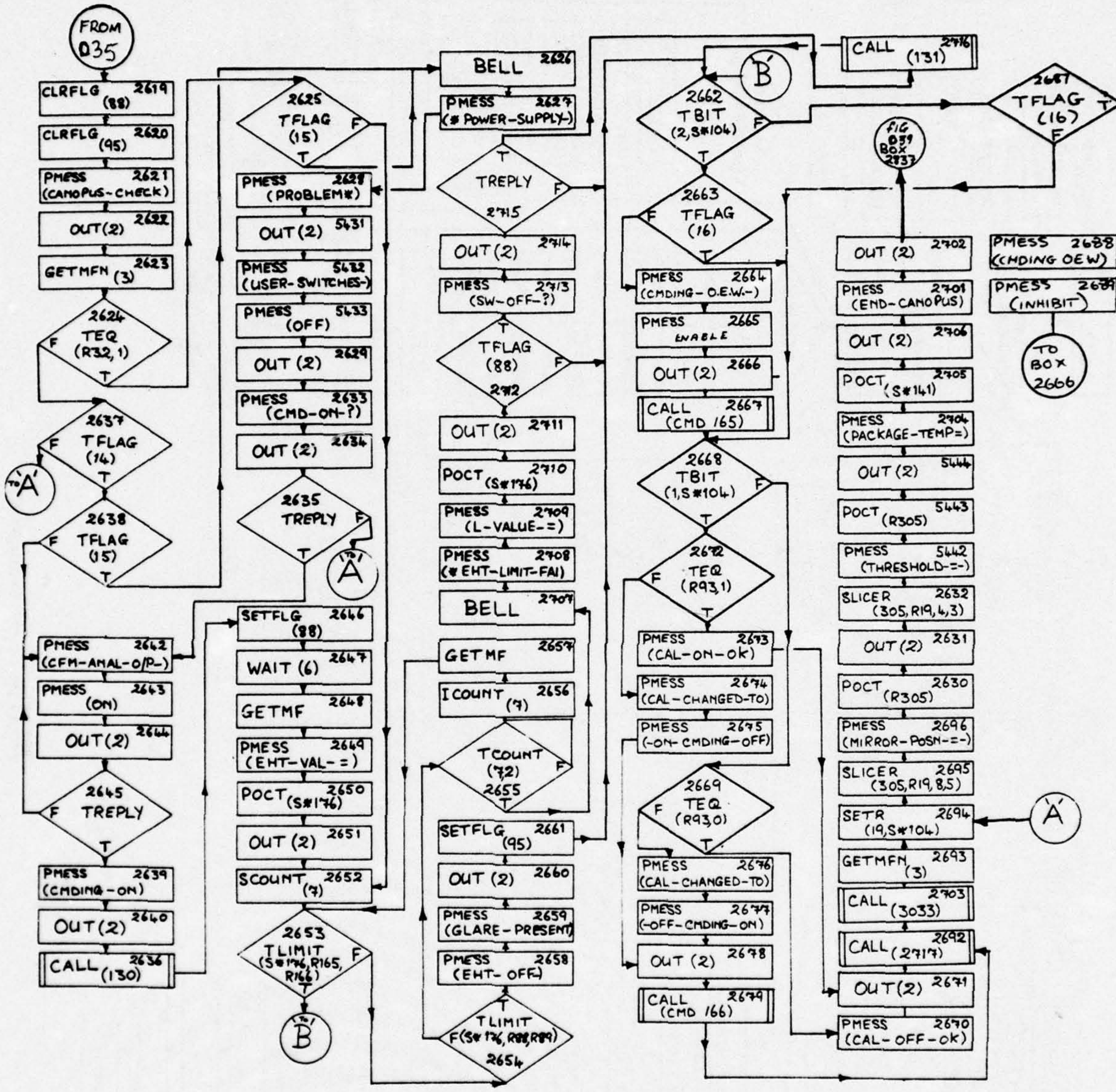


Fig.D36 Canopus evaluation

TR 76016

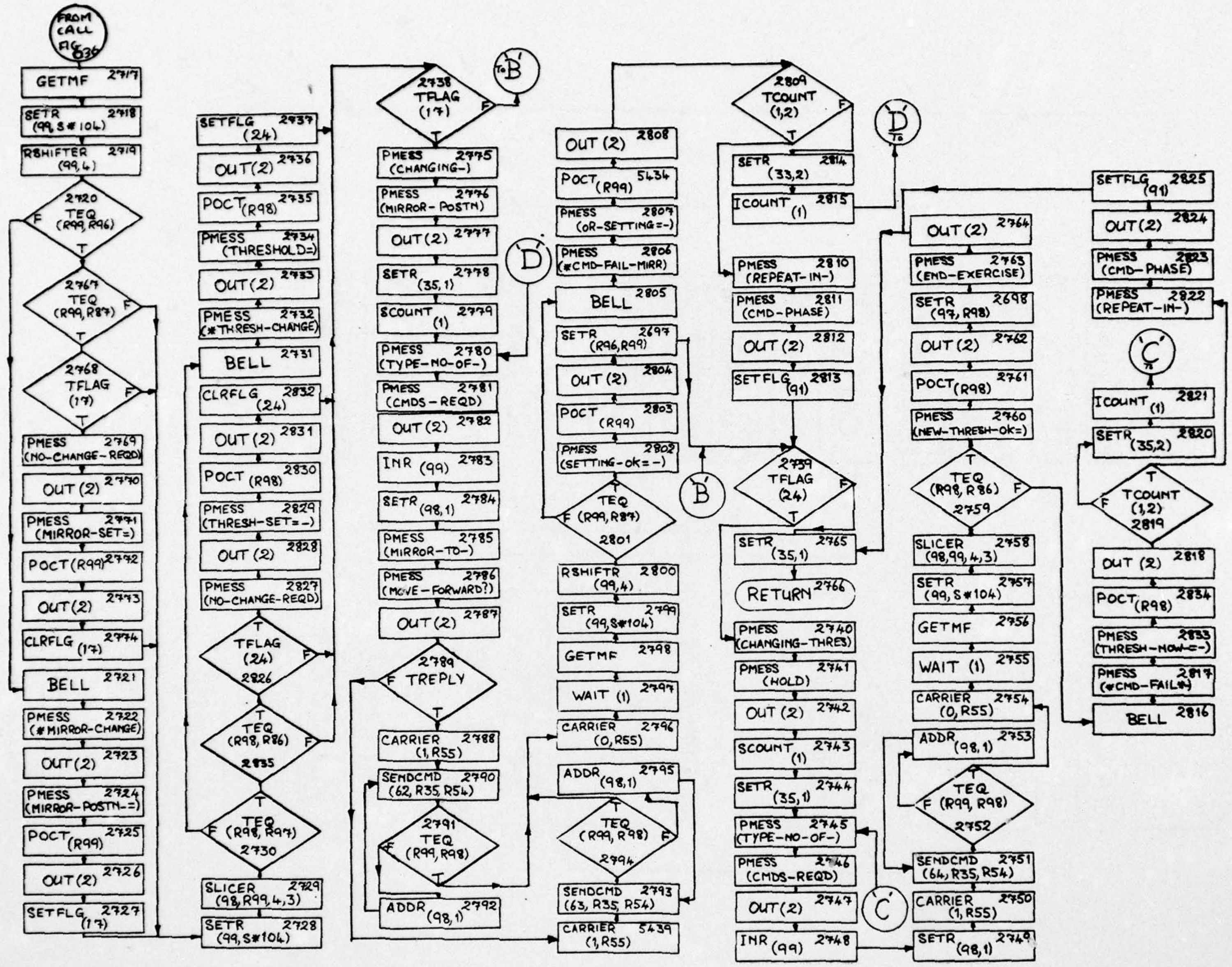


Fig.D37 Canopus evaluation

Fig.D37

Fig.D38

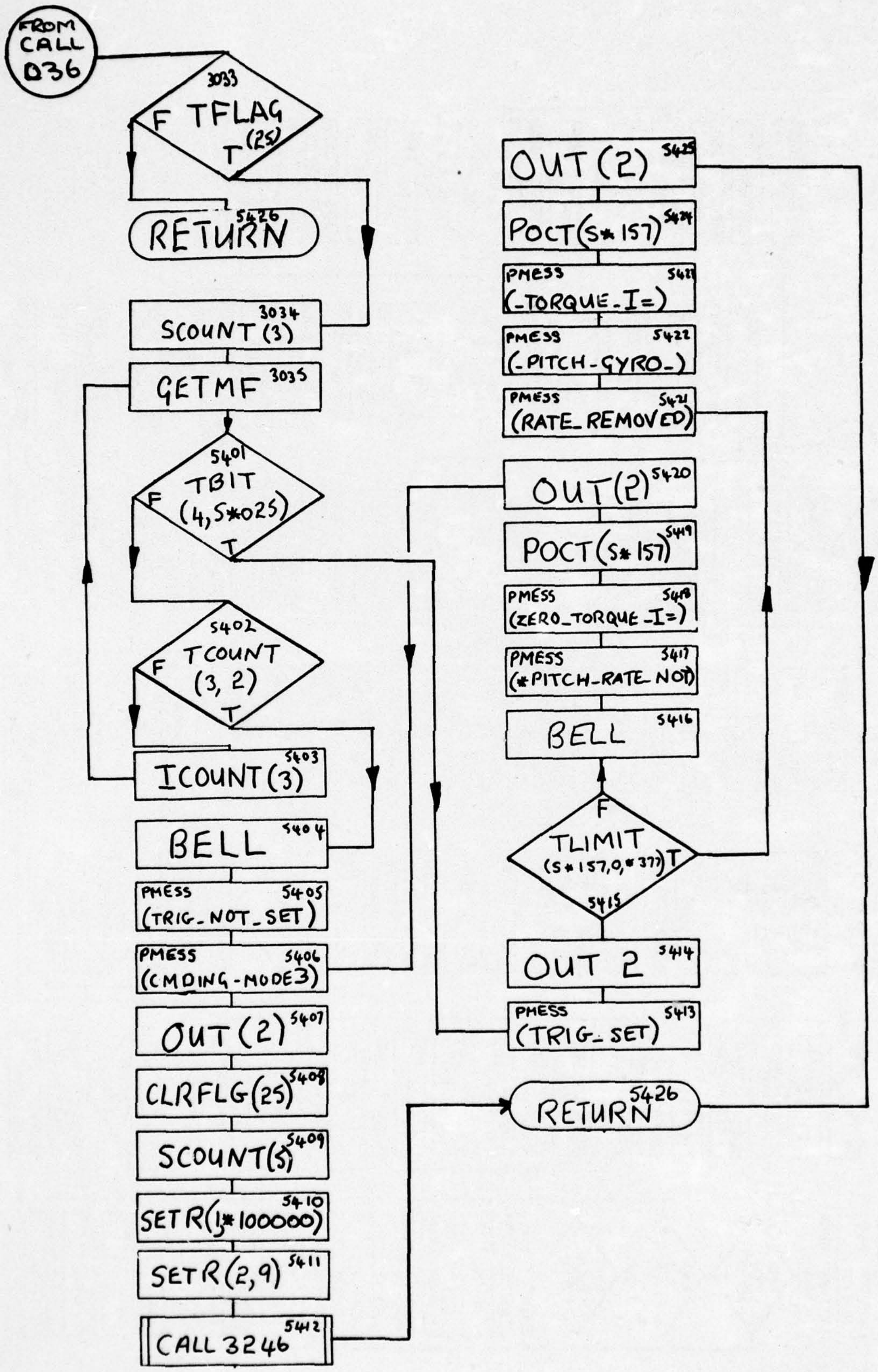


Fig.D38 Canopus evaluation

TR 76016

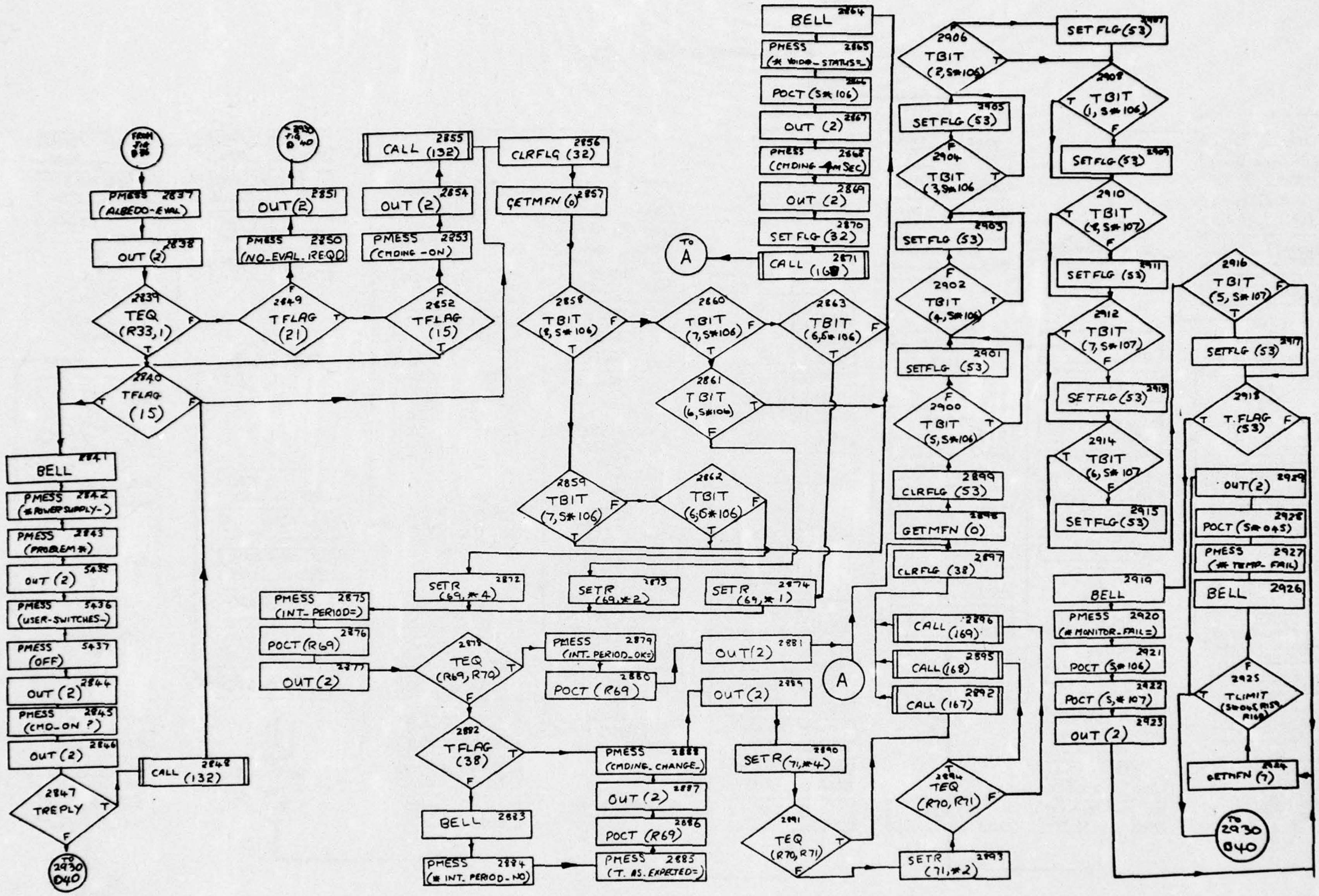


Fig.D39 Albedo evaluation

Fig.D39

Fig.D40

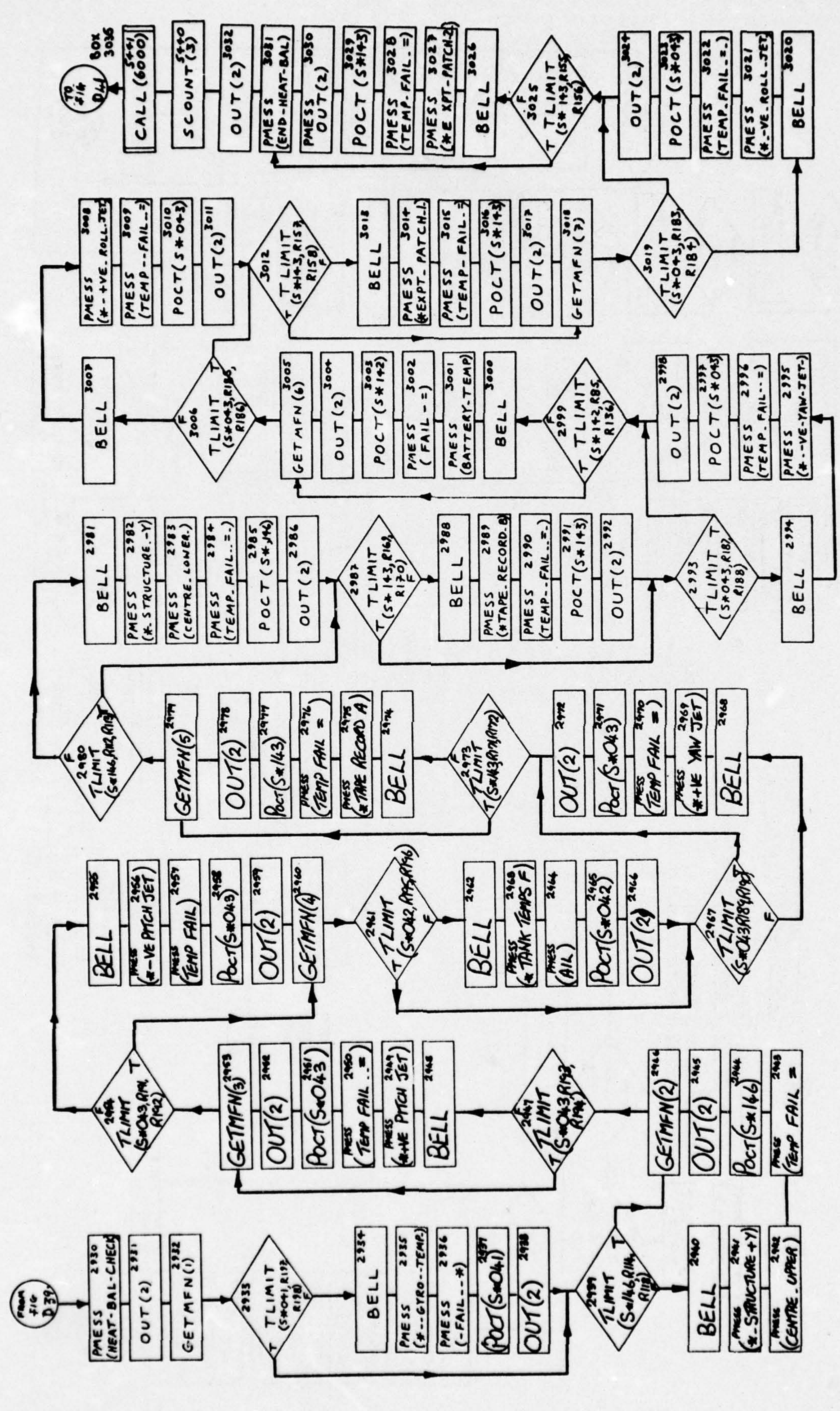


Fig.D40 Heat balance check

TR 76016

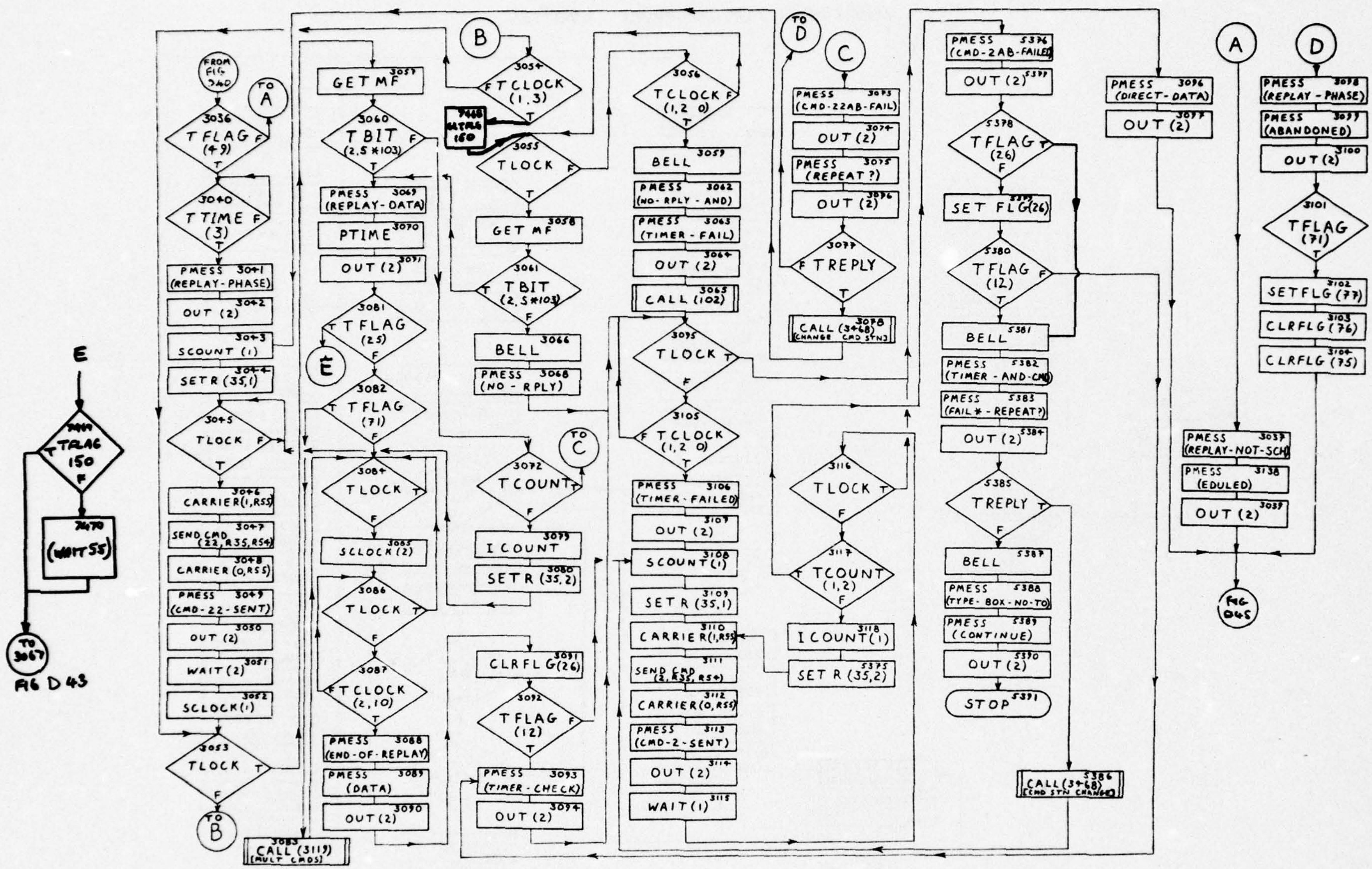


Fig.D41 Replay phase

Fig.D42

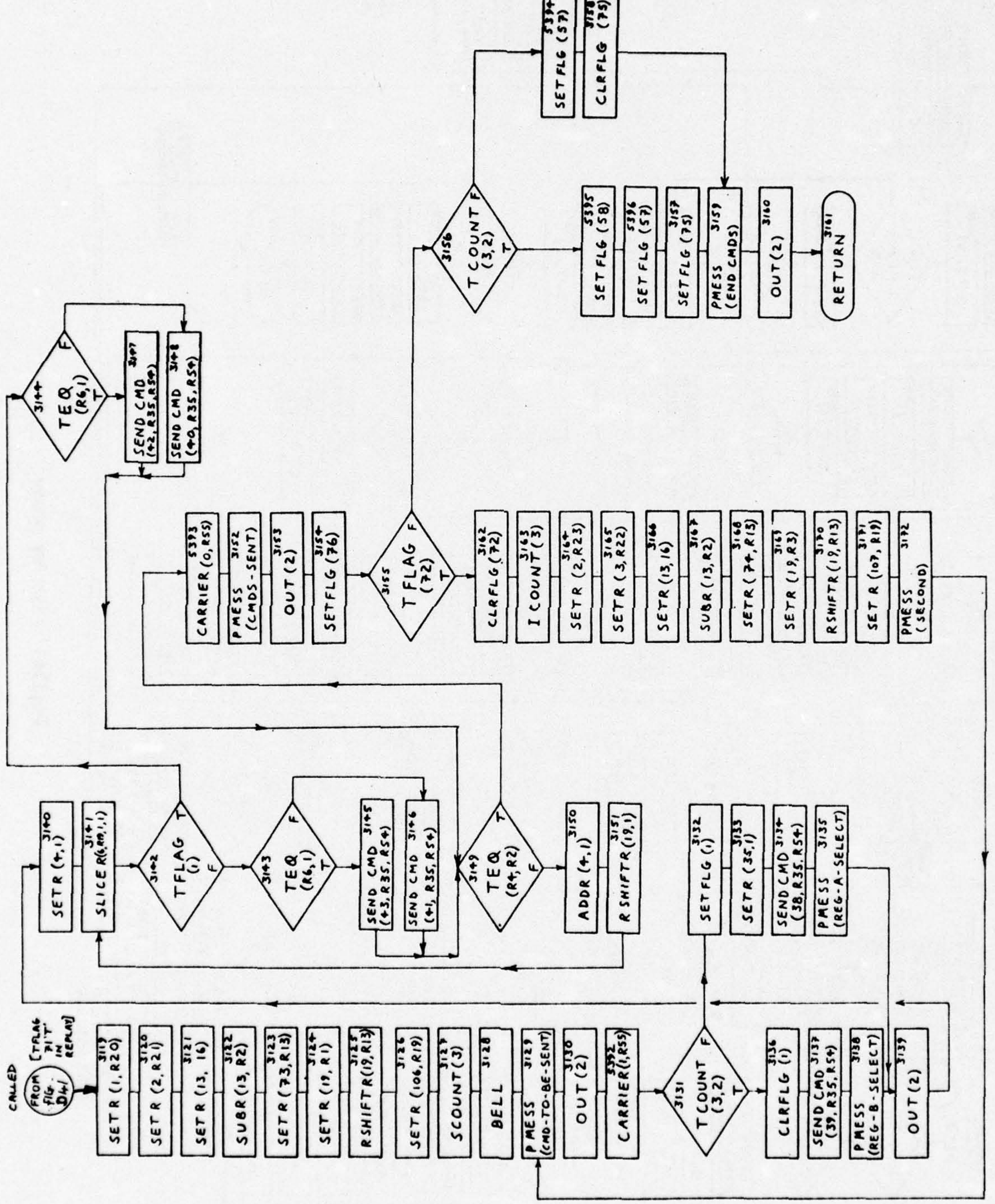


Fig.D42 Commands sent during replay

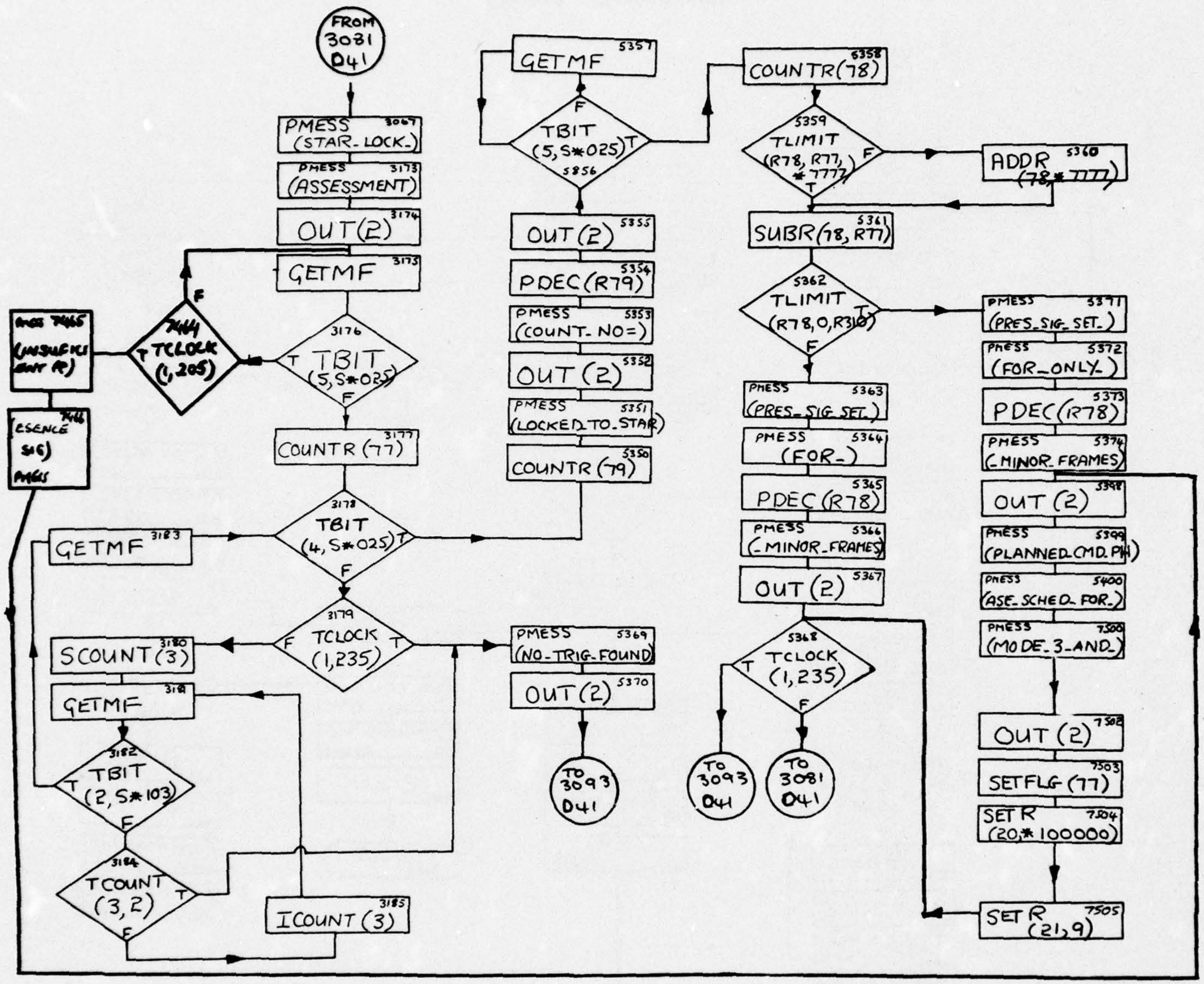


Fig.D43 Star lock assessment

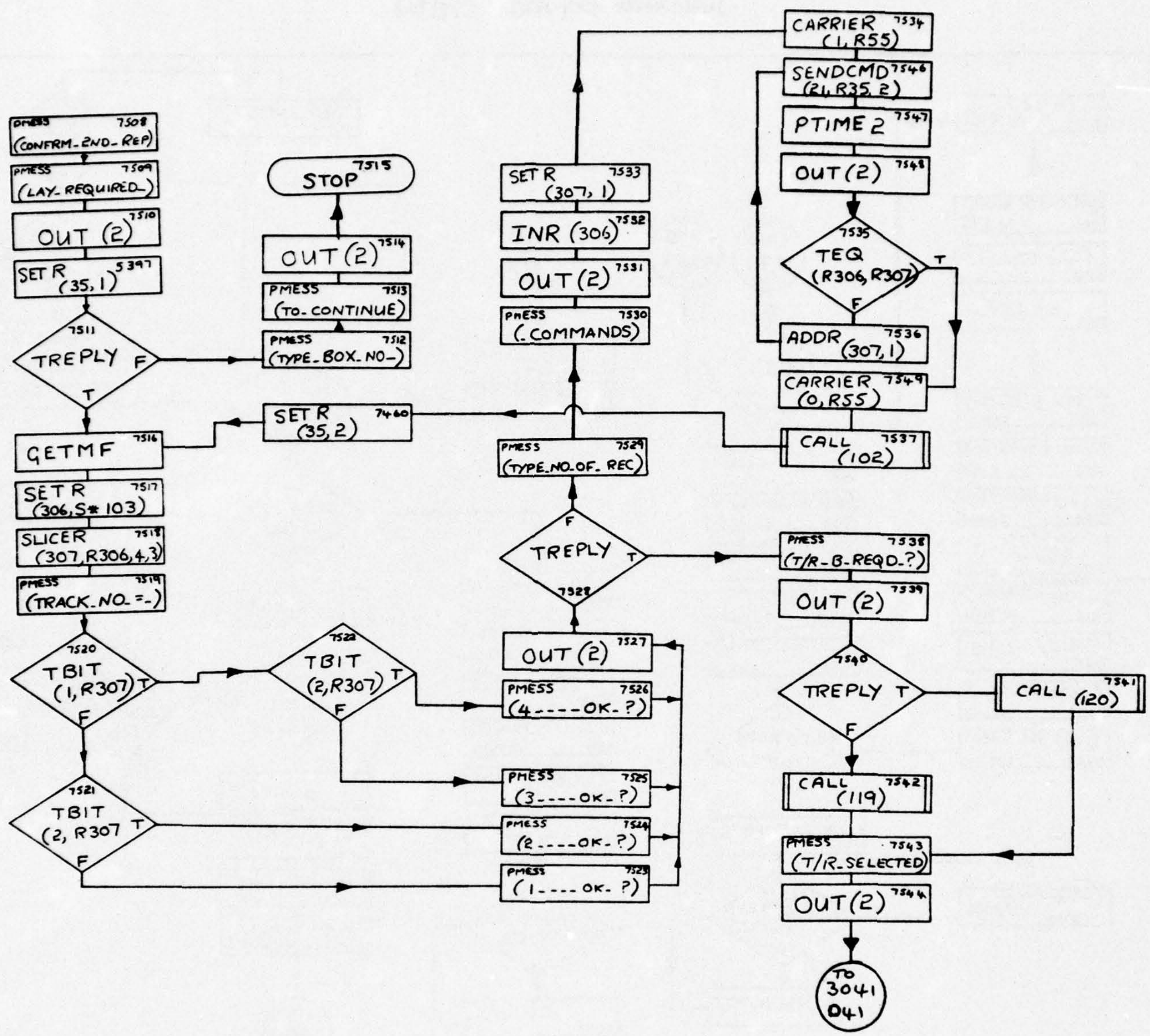


Fig.D44 Second replay

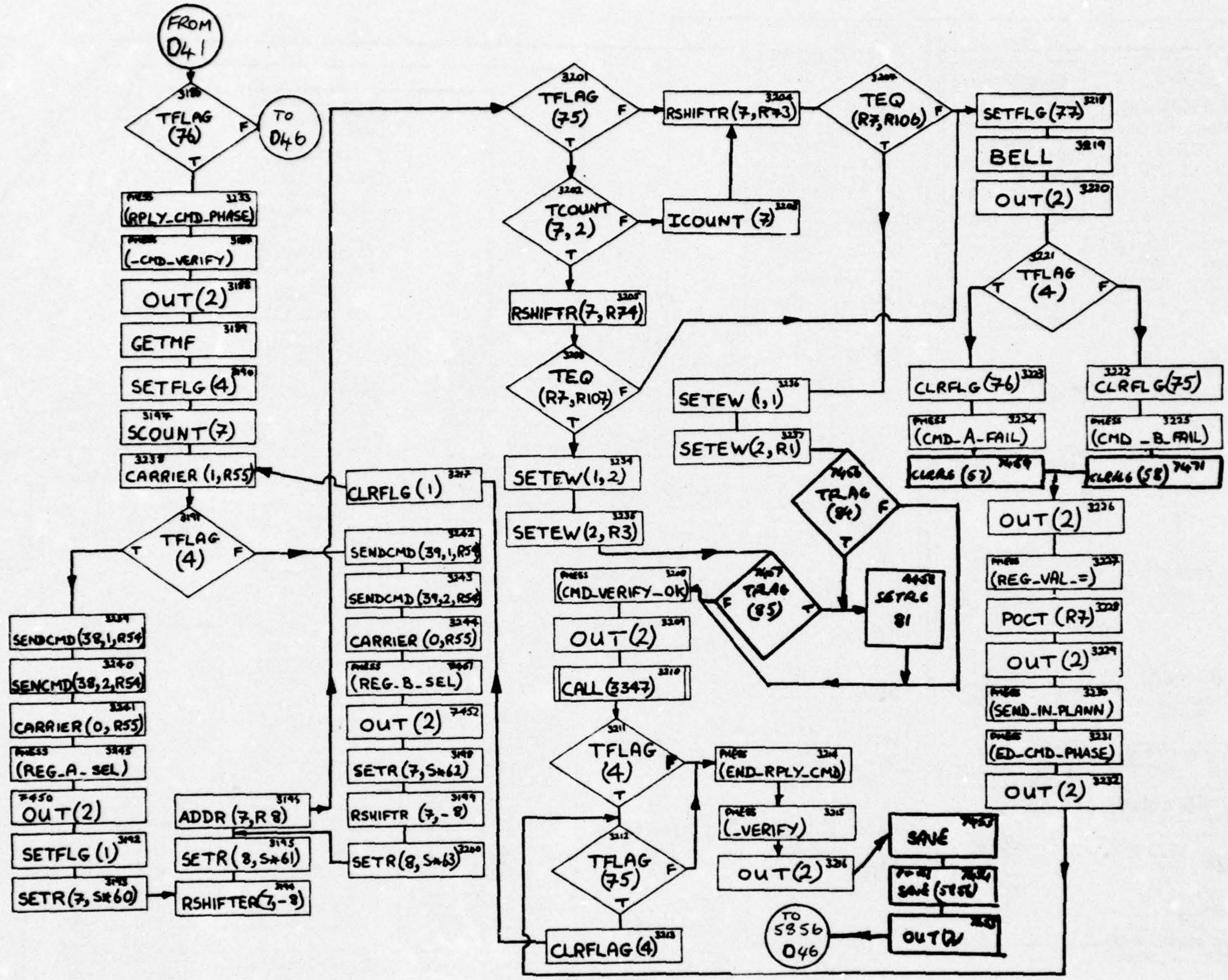


Fig.D45 Replay command verify

Fig.D46

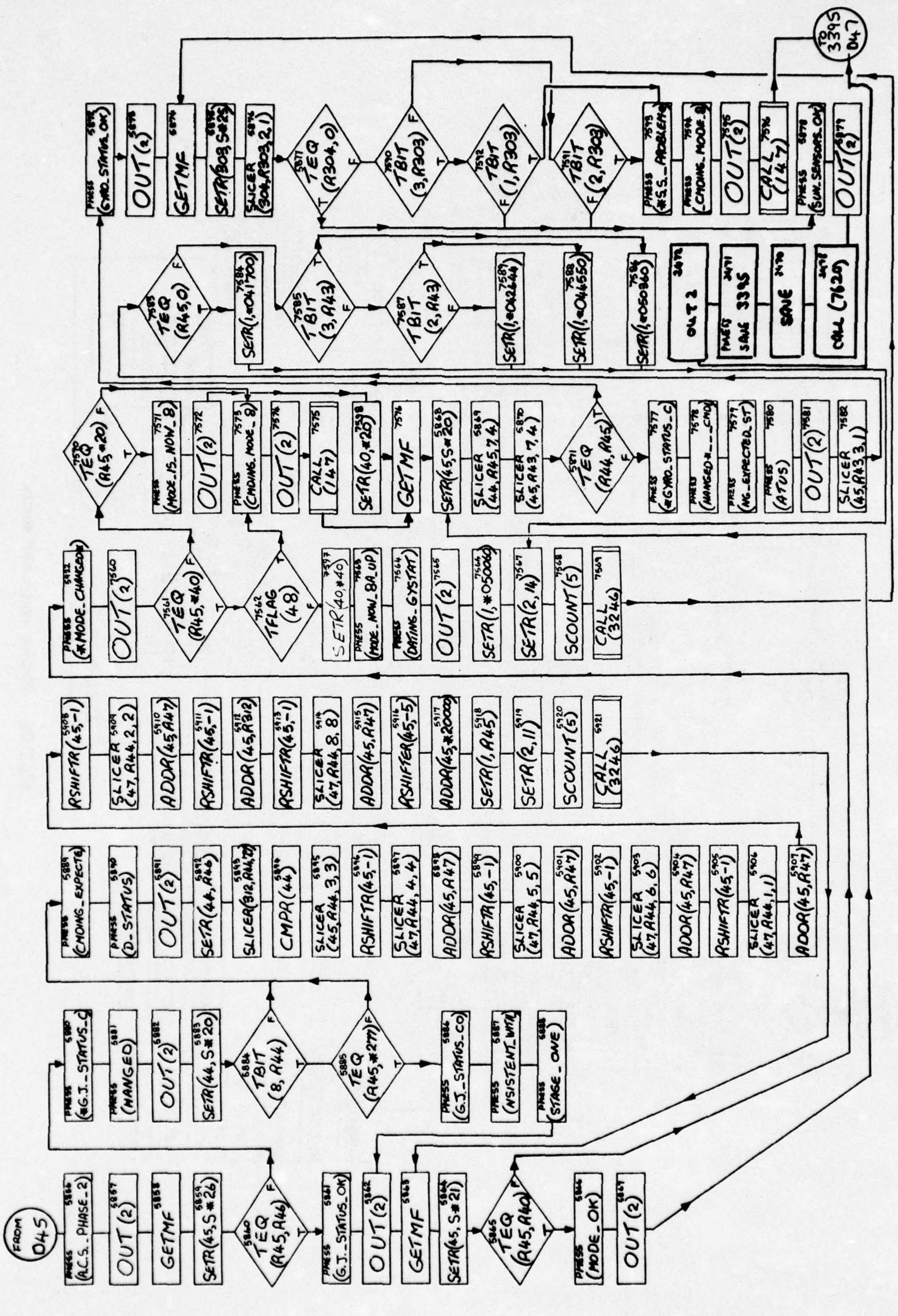


Fig.D46 ACS Phase 2

TR 76016

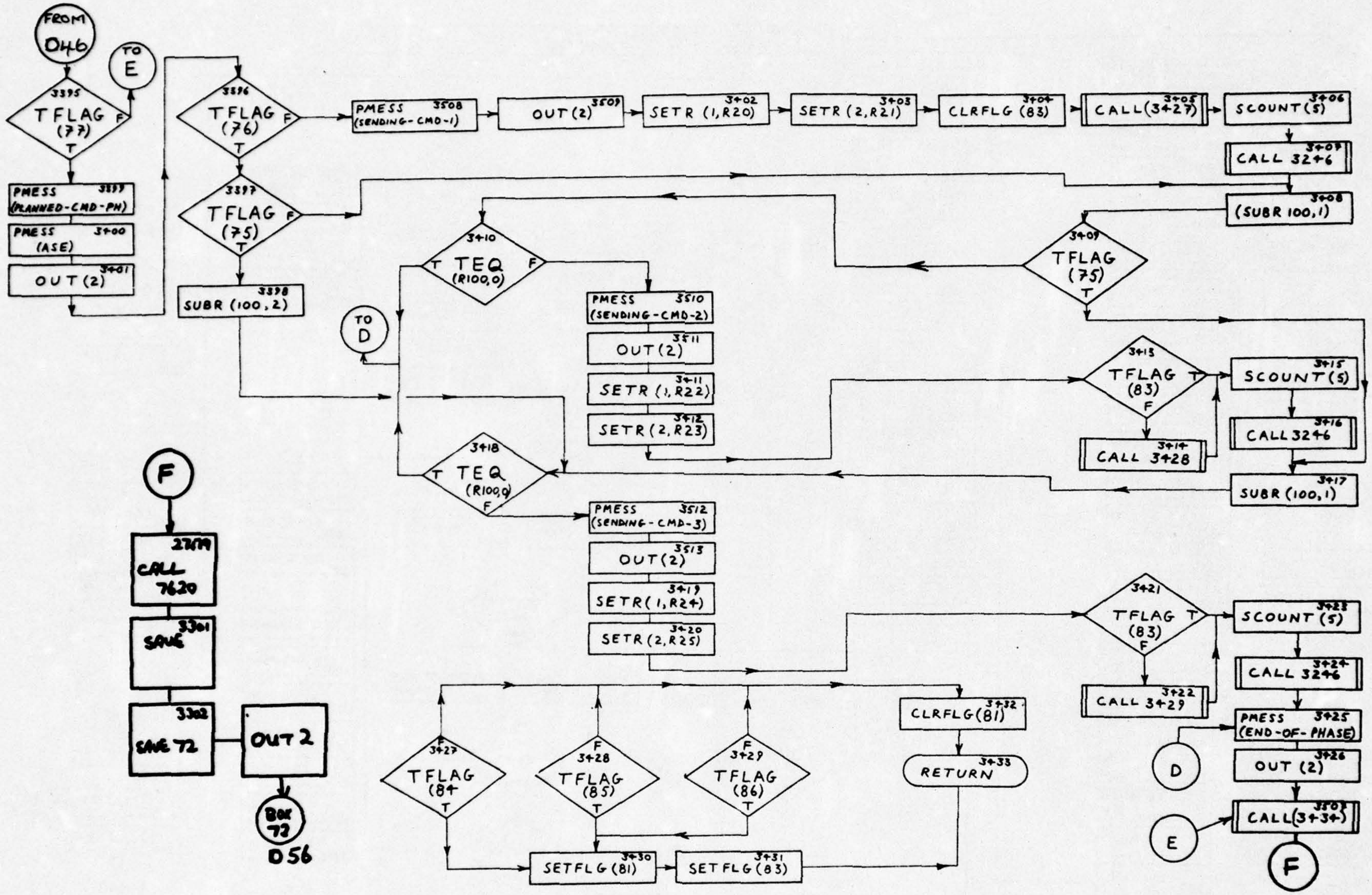


Fig.D47 Planned commands

Fig.D48

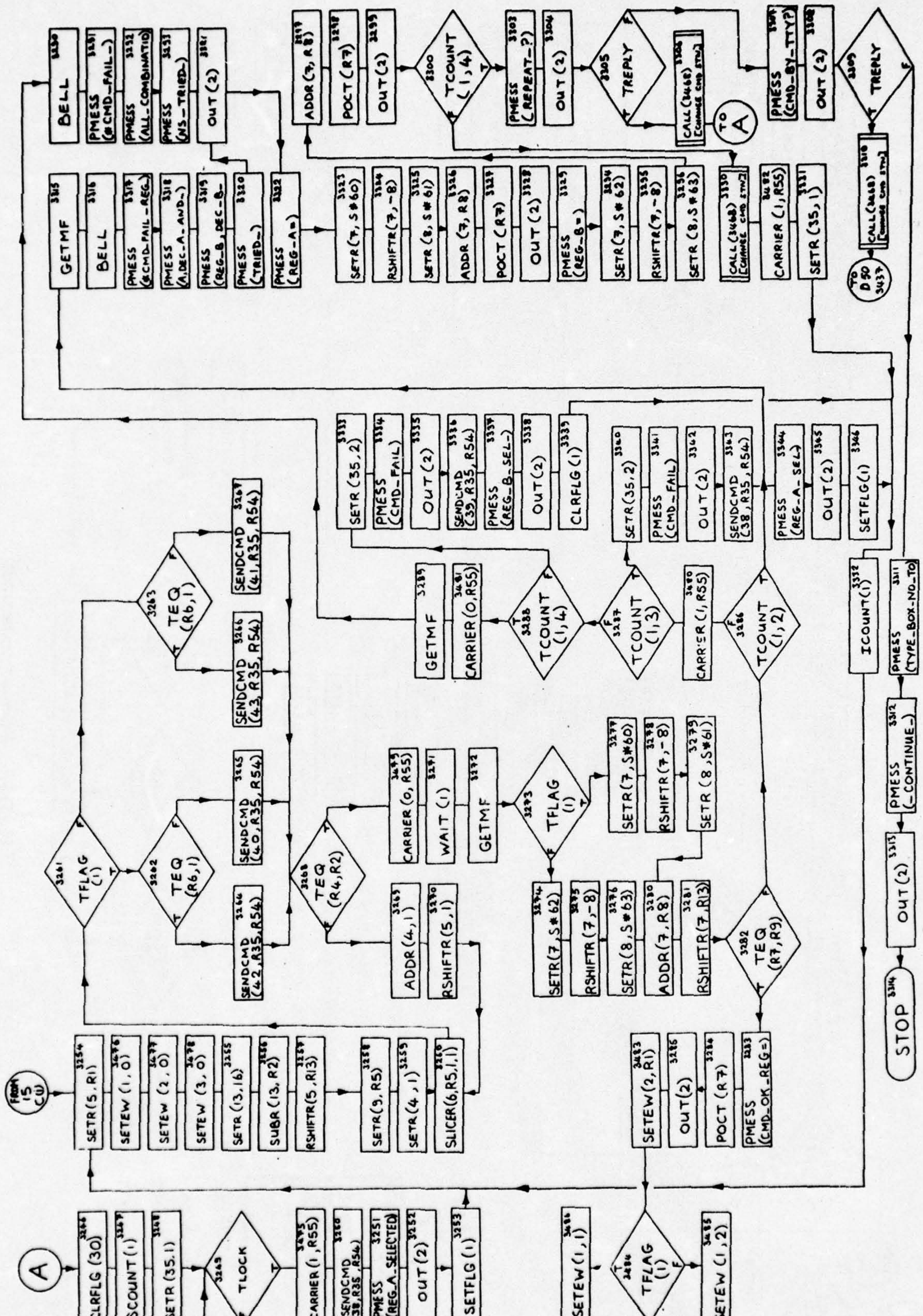


Fig.D48 Multiple command sending phase

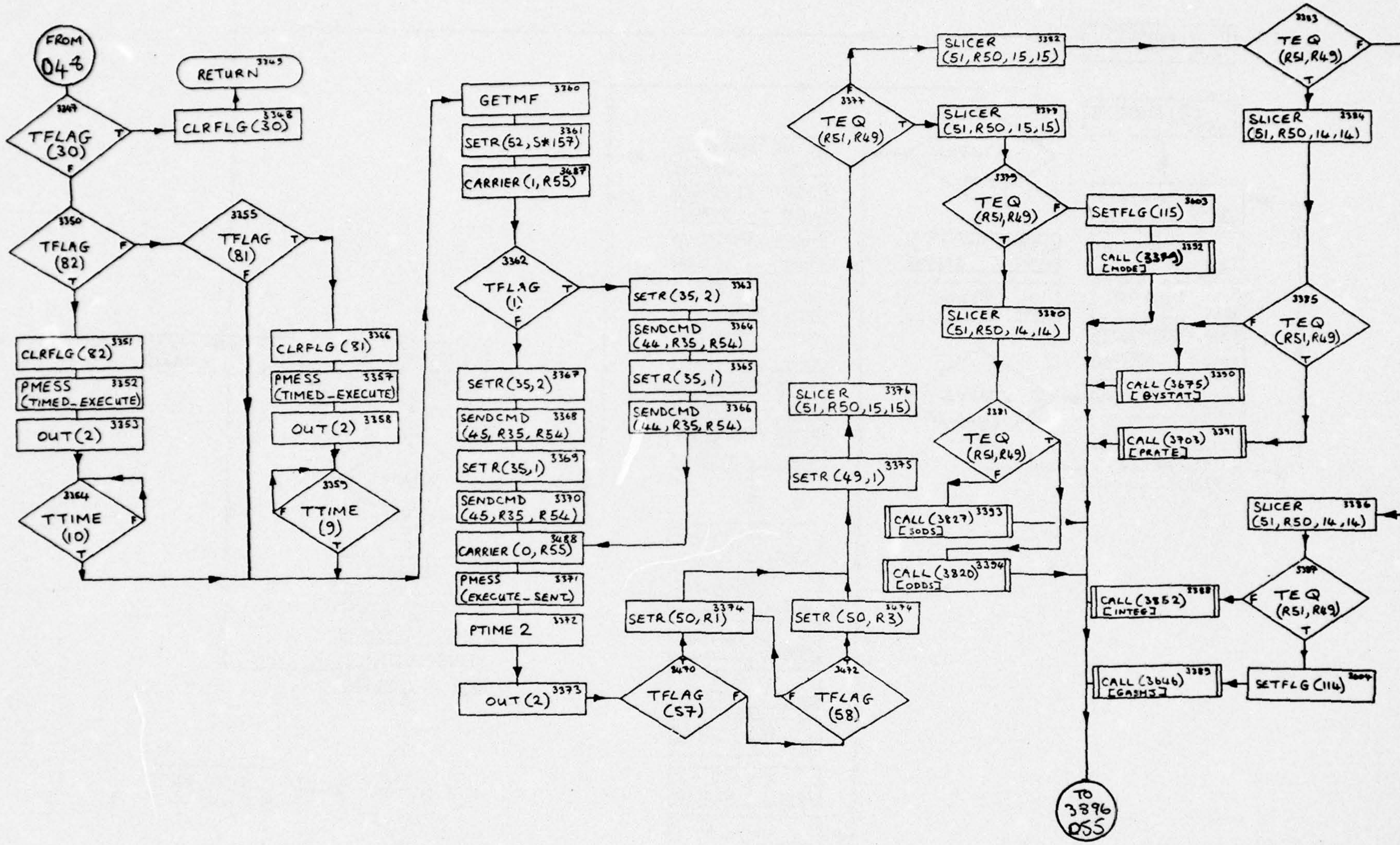


Fig.D49 Time dependence check

Fig.D50

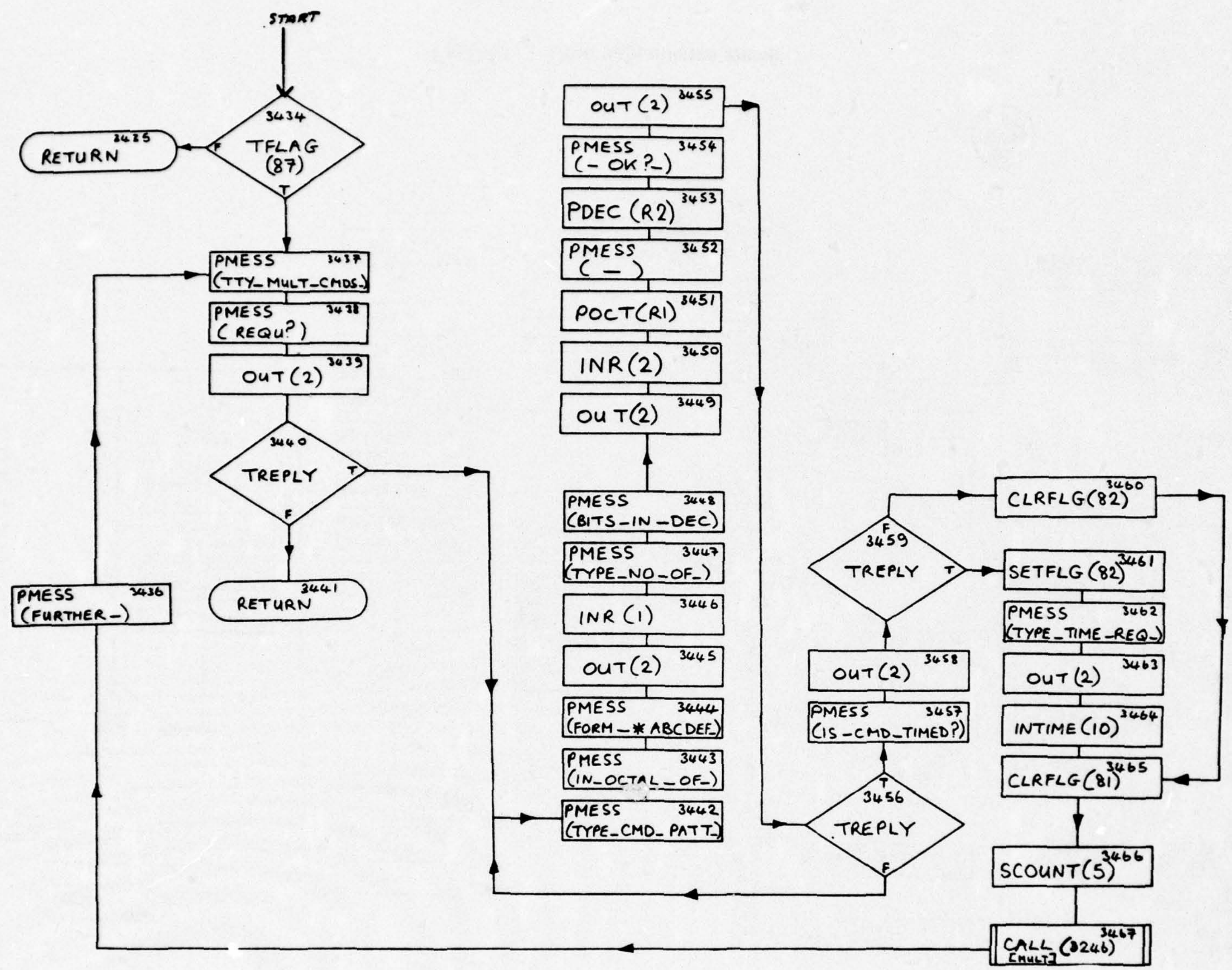


Fig.D50 Teletype multiple command phase

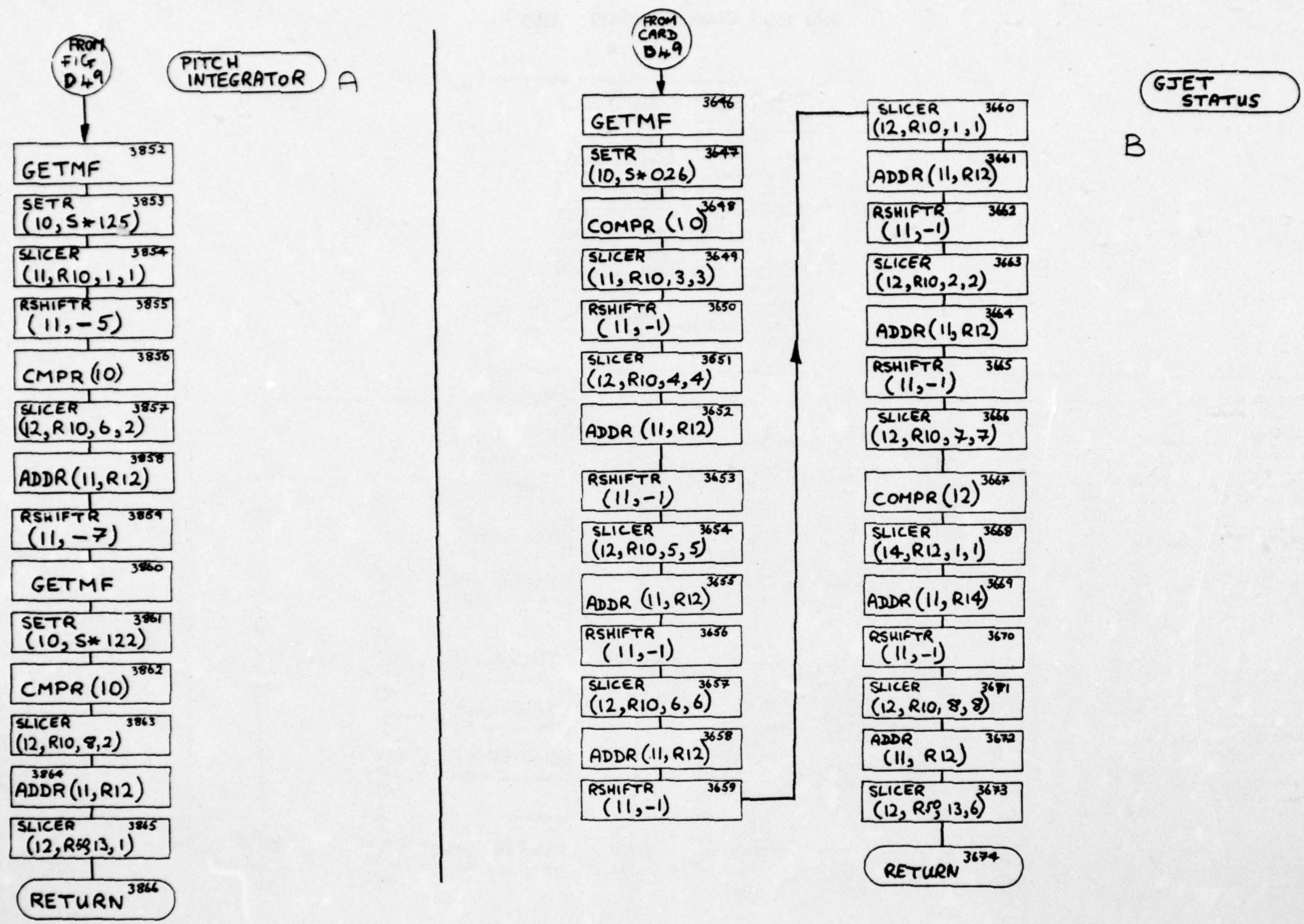


Fig.D51 Command verify

Fig.D51

Fig.D52

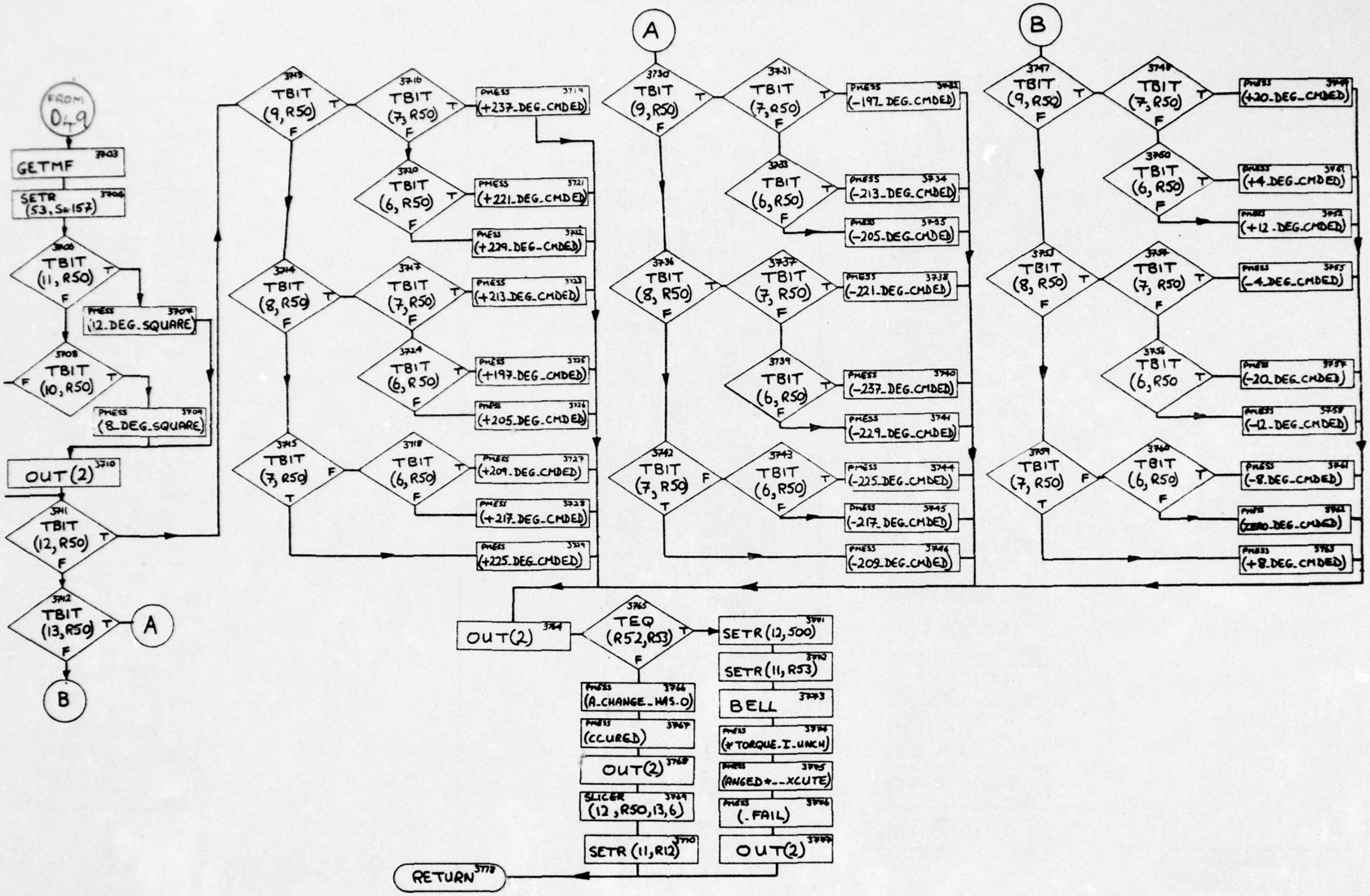


Fig.D52 Command verify pitch rate

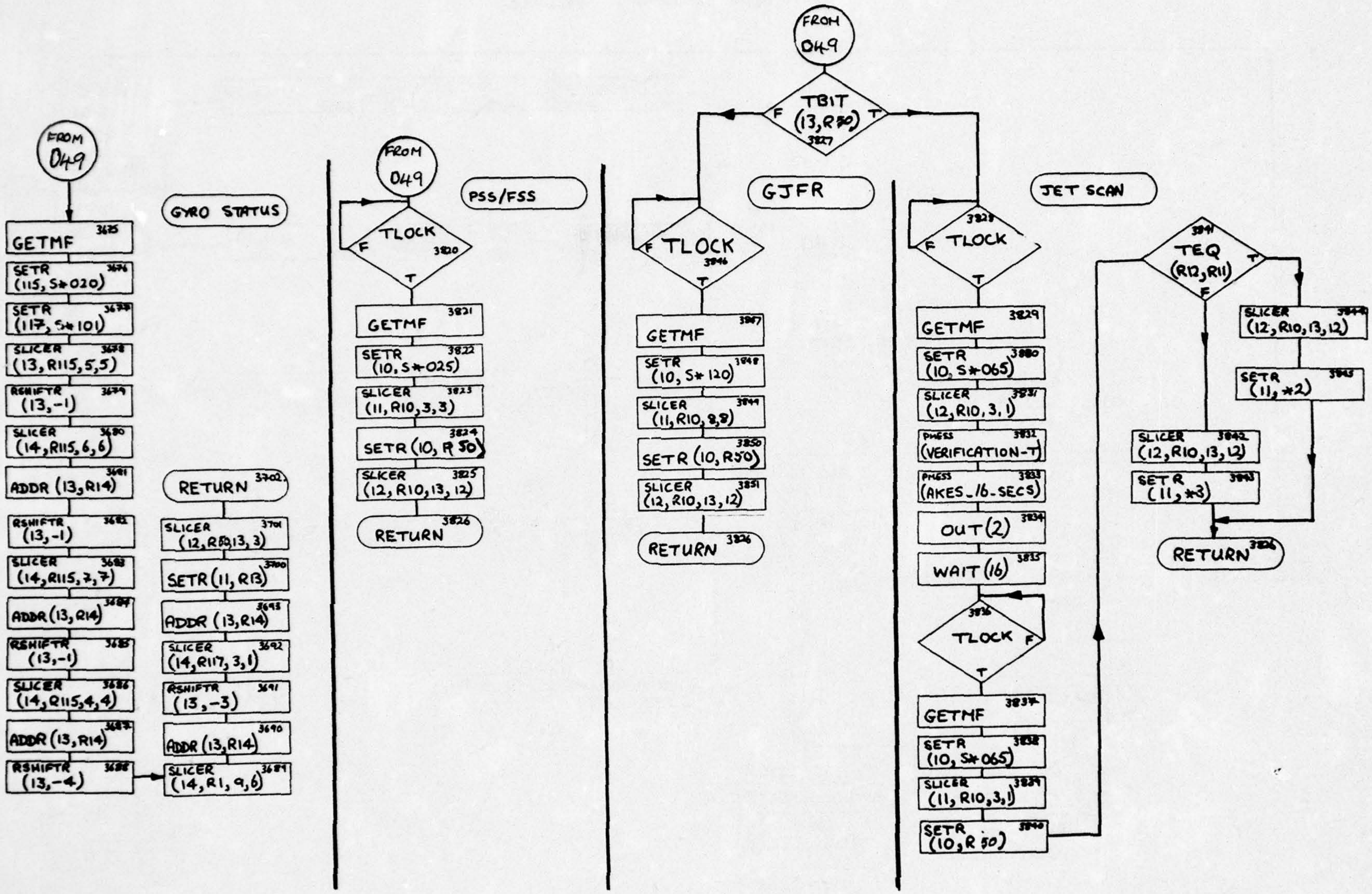


Fig.D53 Command verify

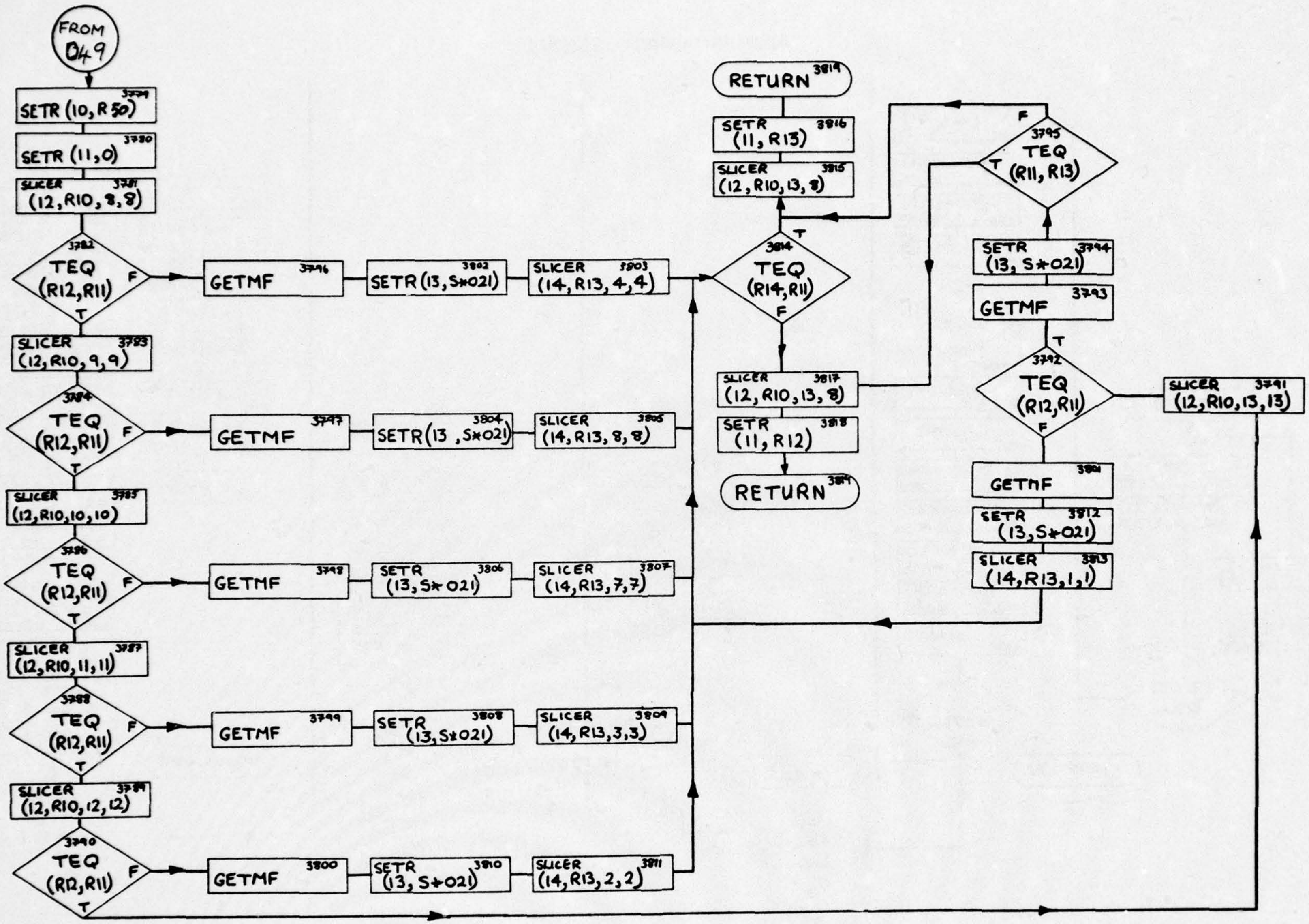


Fig.D54 Command verify mode

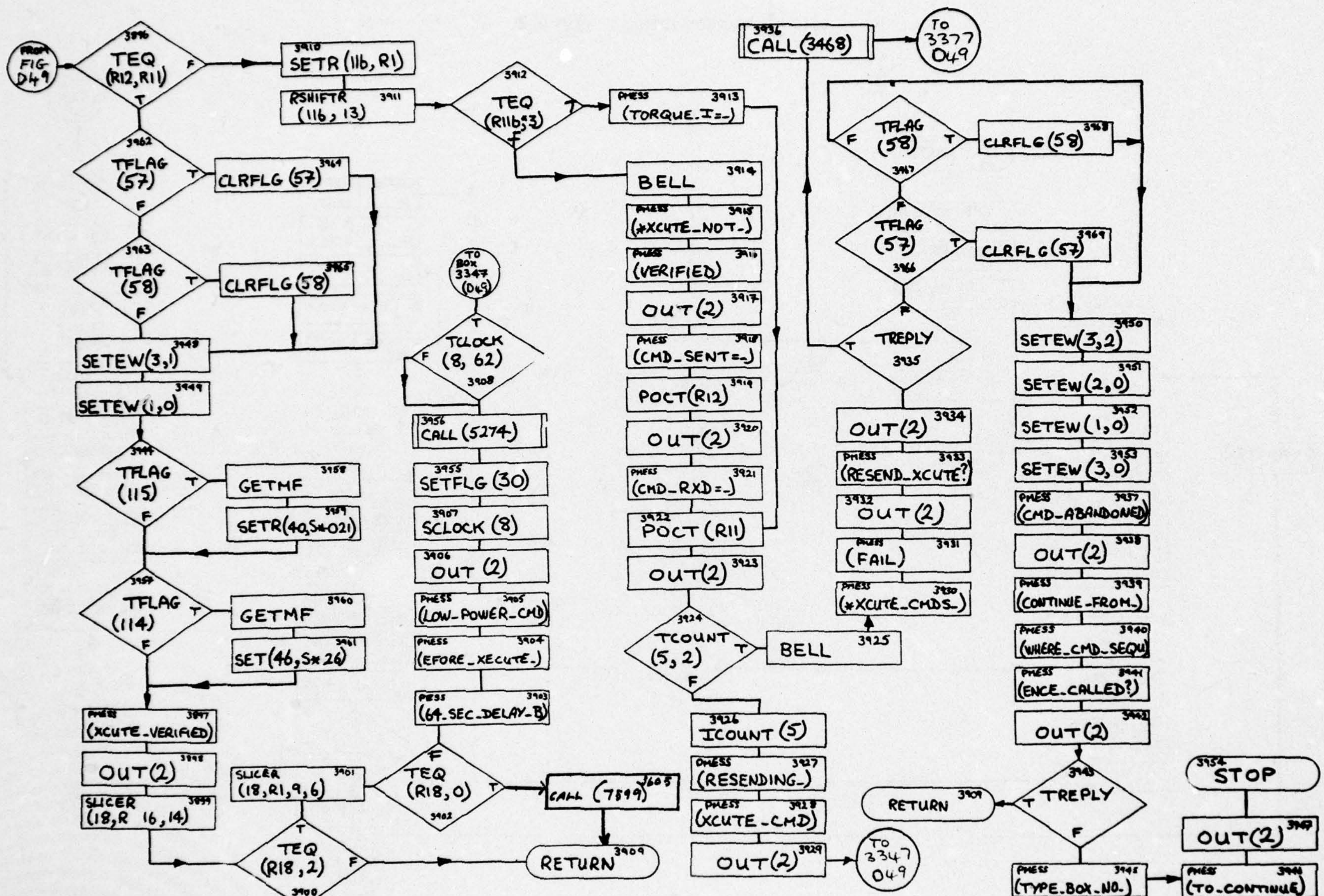


Fig.D55 Actual verify gyro status

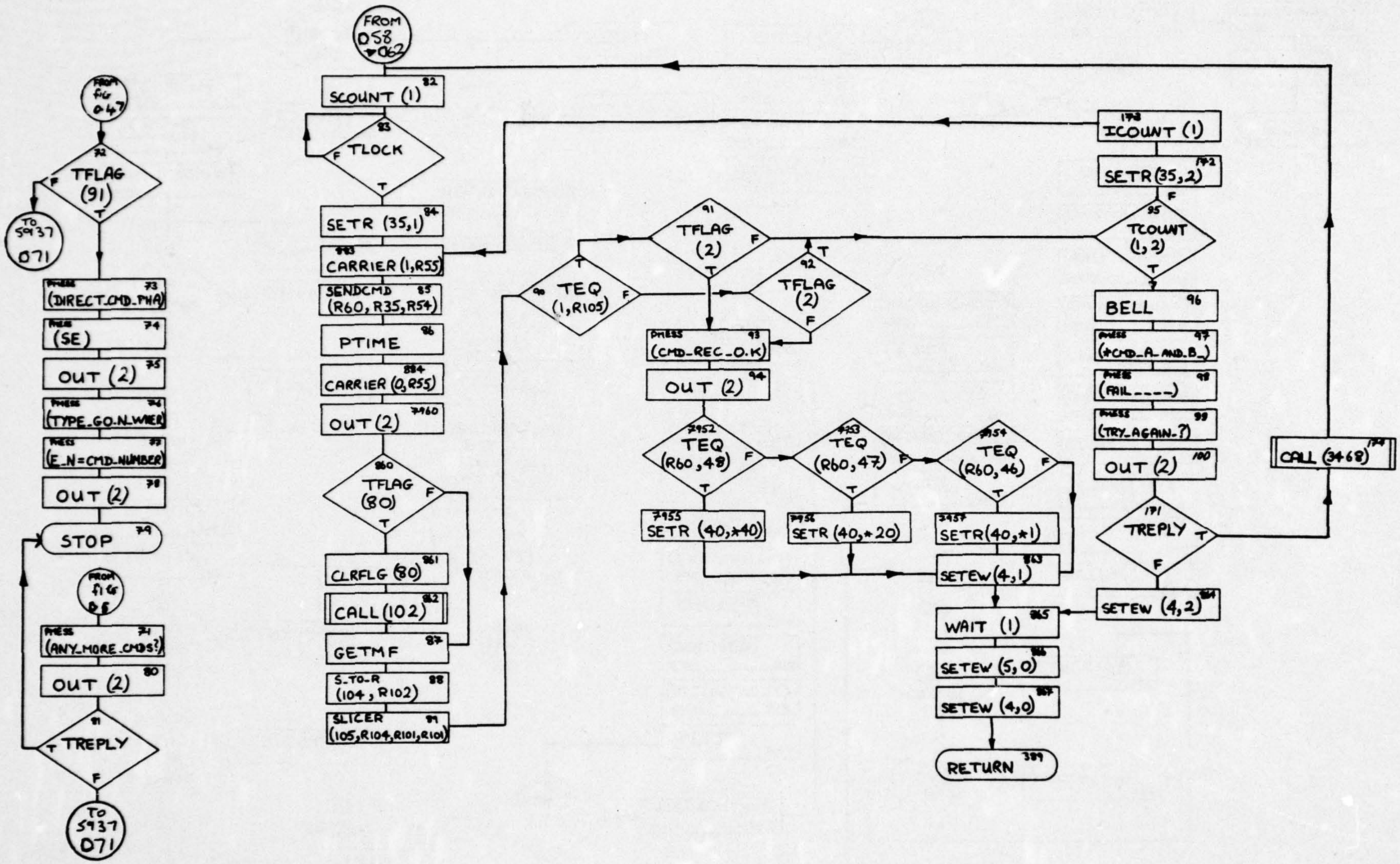
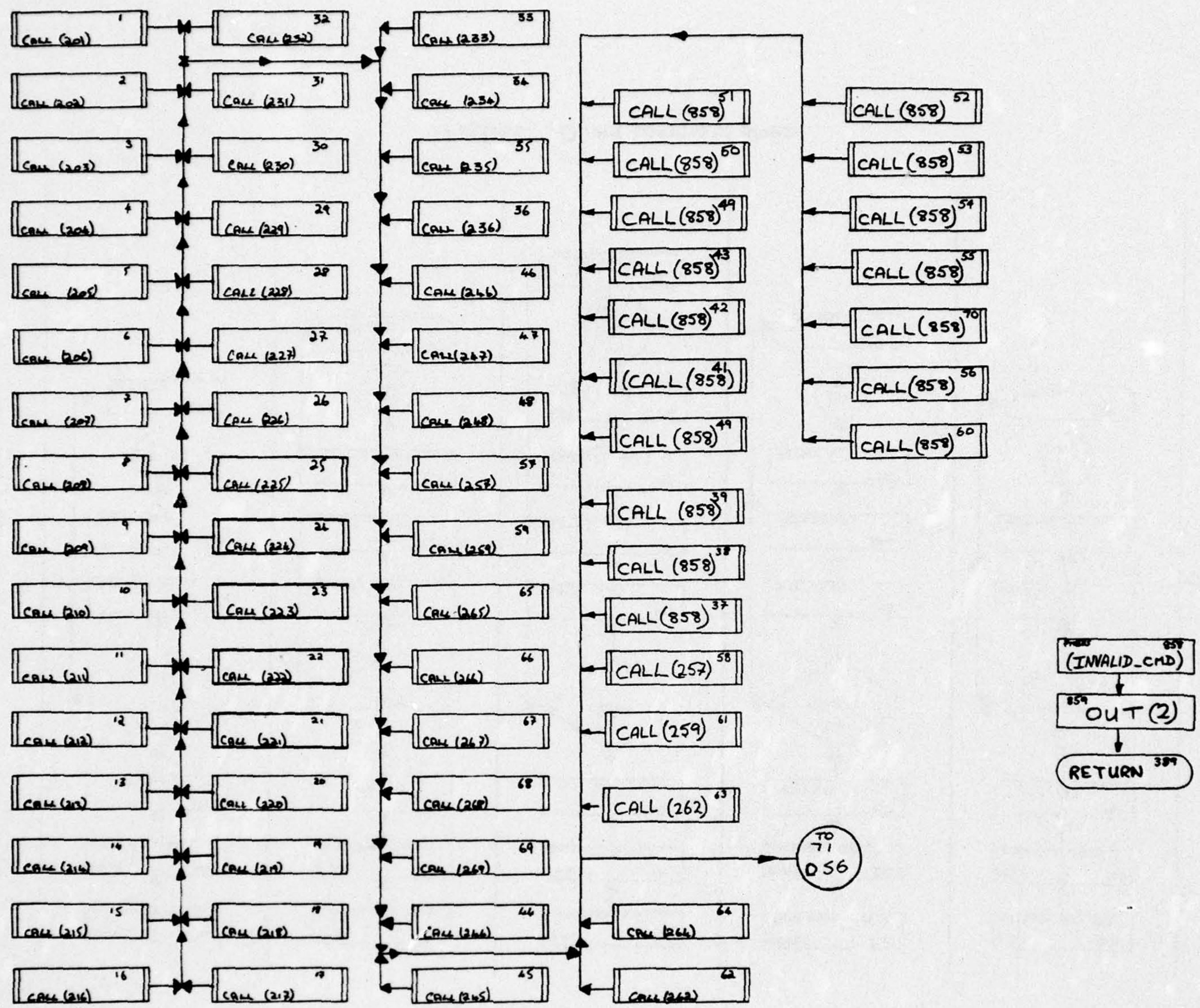


Fig.D56 Direct command phase



Call command routing

Fig.D57 Direct command phase

Fig.D58

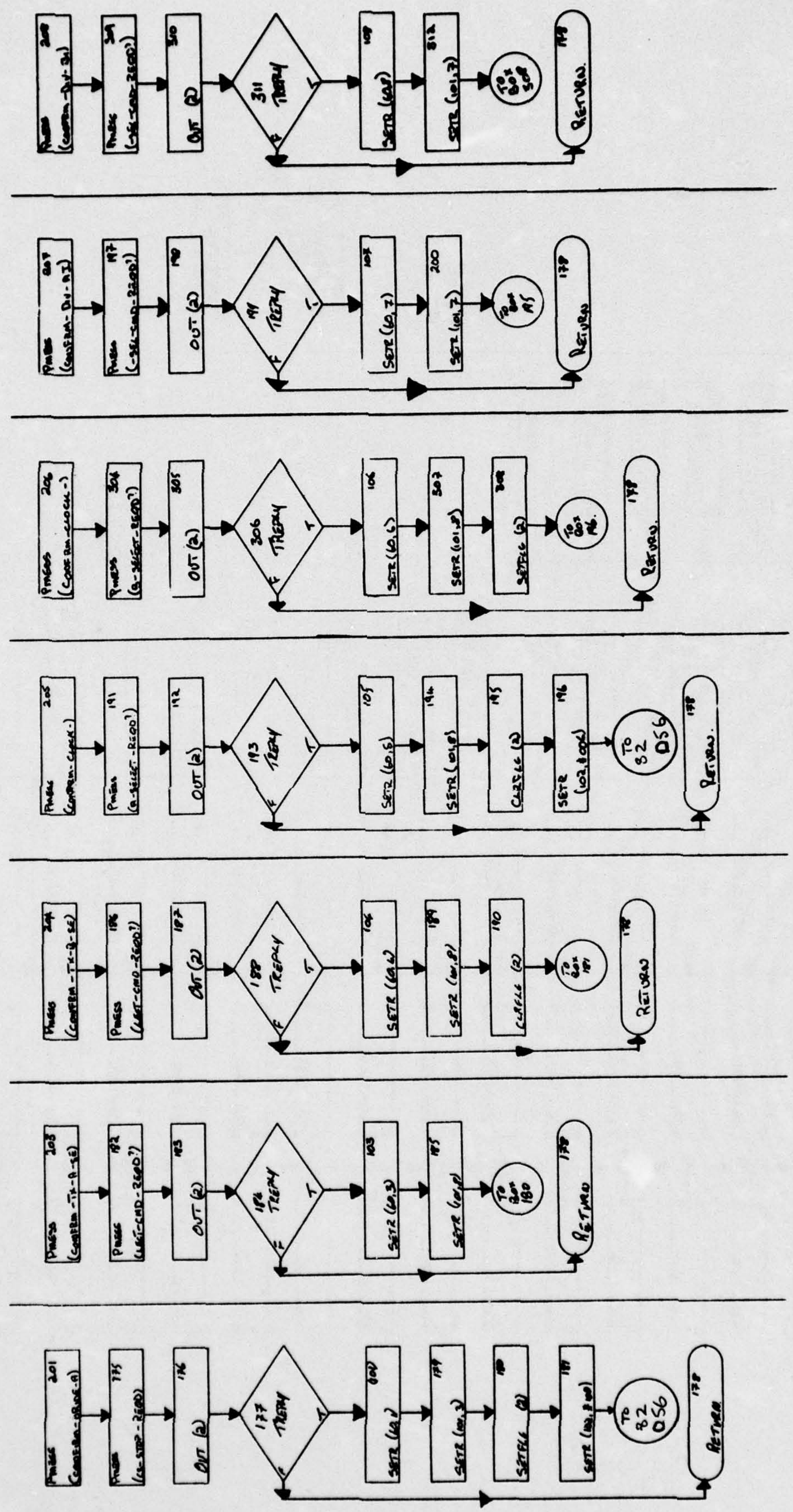


Fig.D58 Direct command phase

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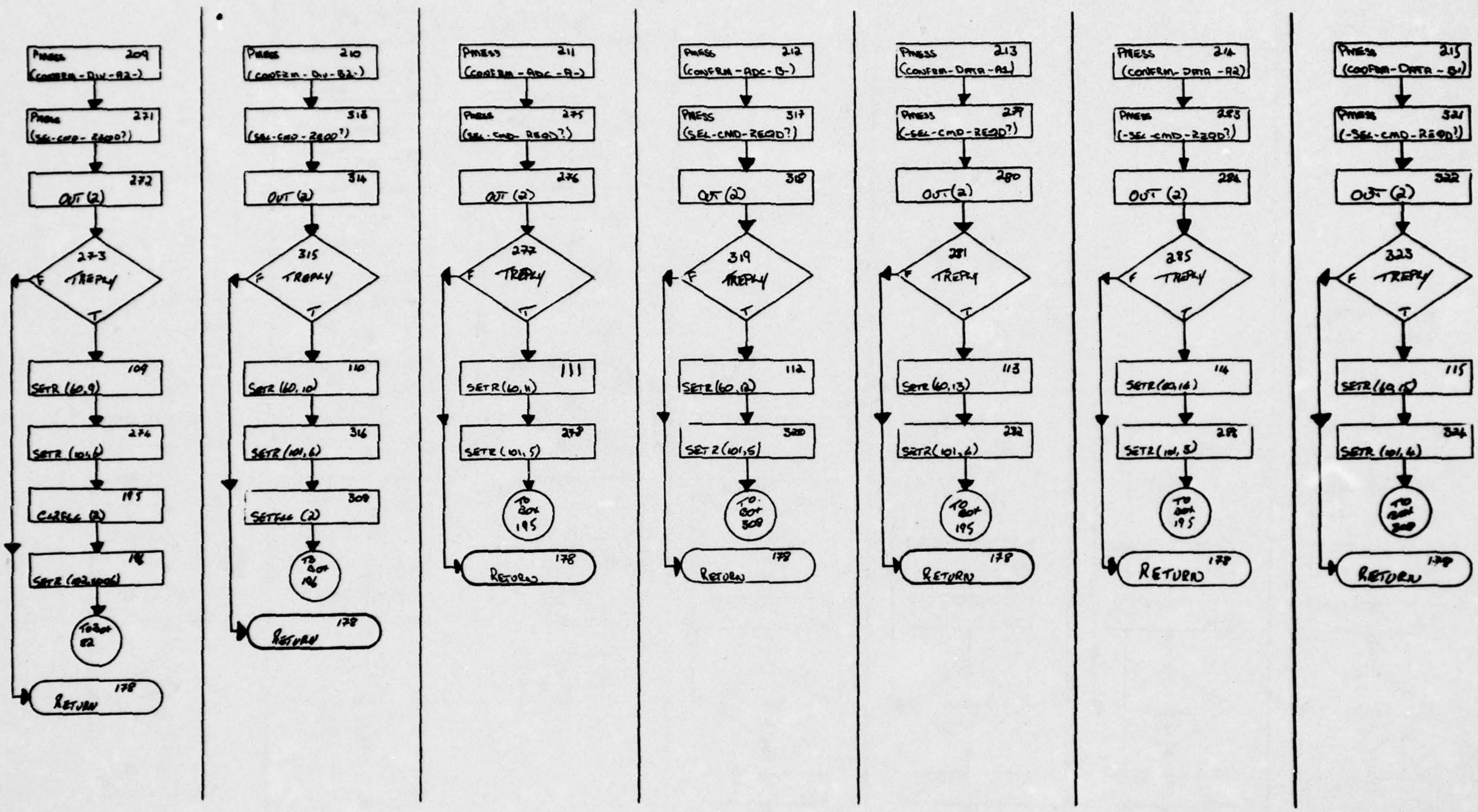
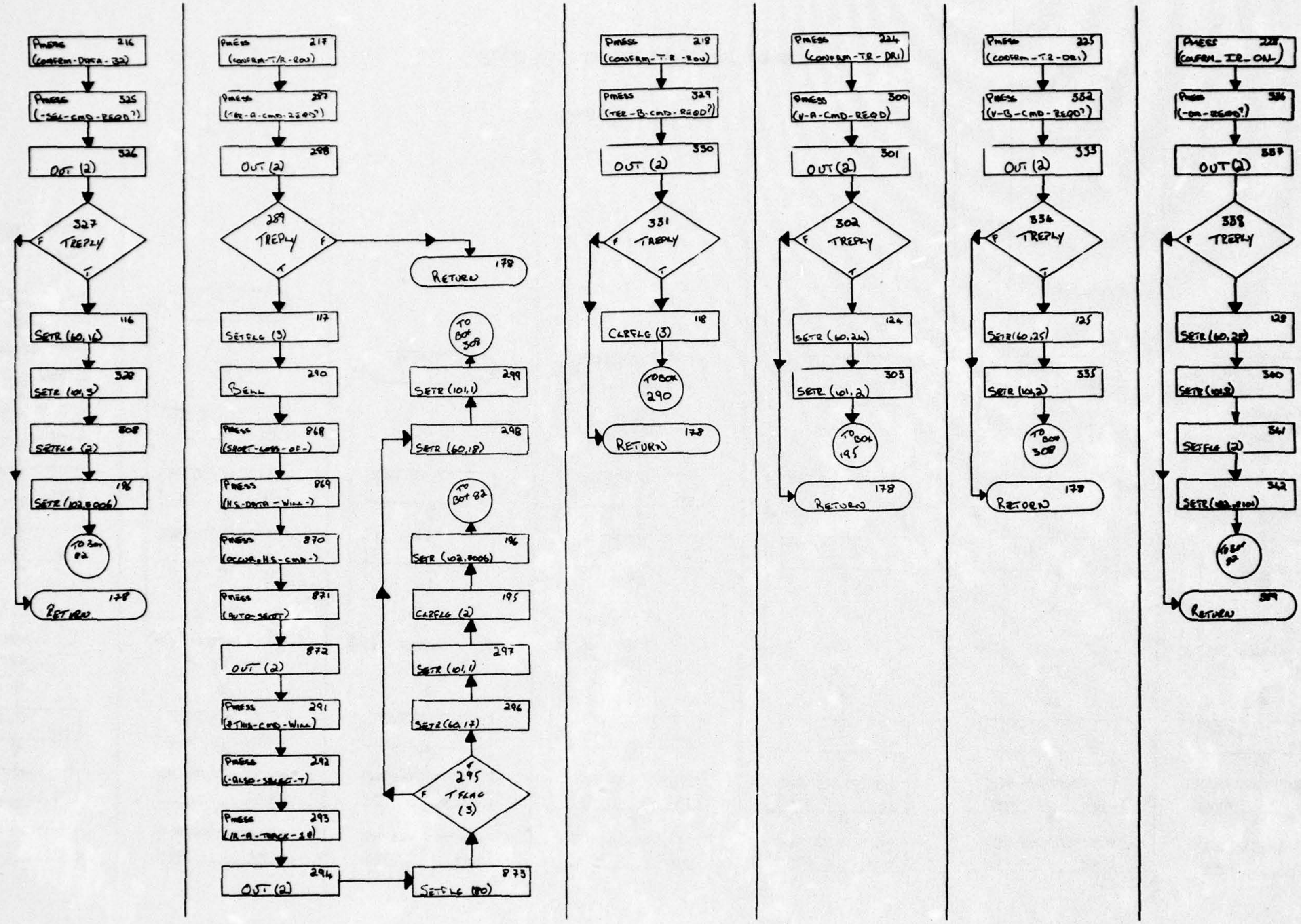


Commands 9 to 15

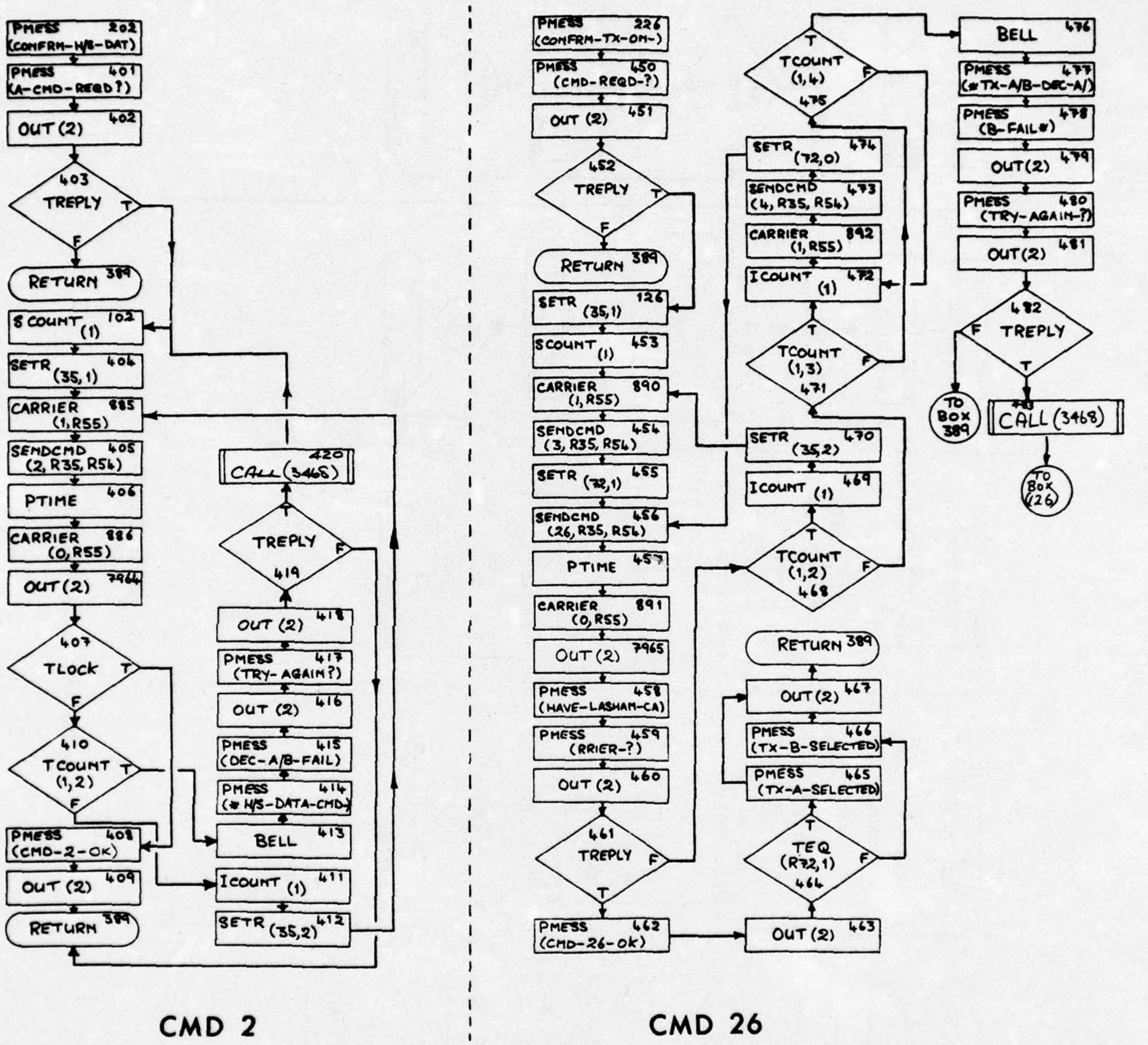
Fig.D59 Direct command phase

Fig.D60



Commands 16, 17, 18, 24, 25 and 28

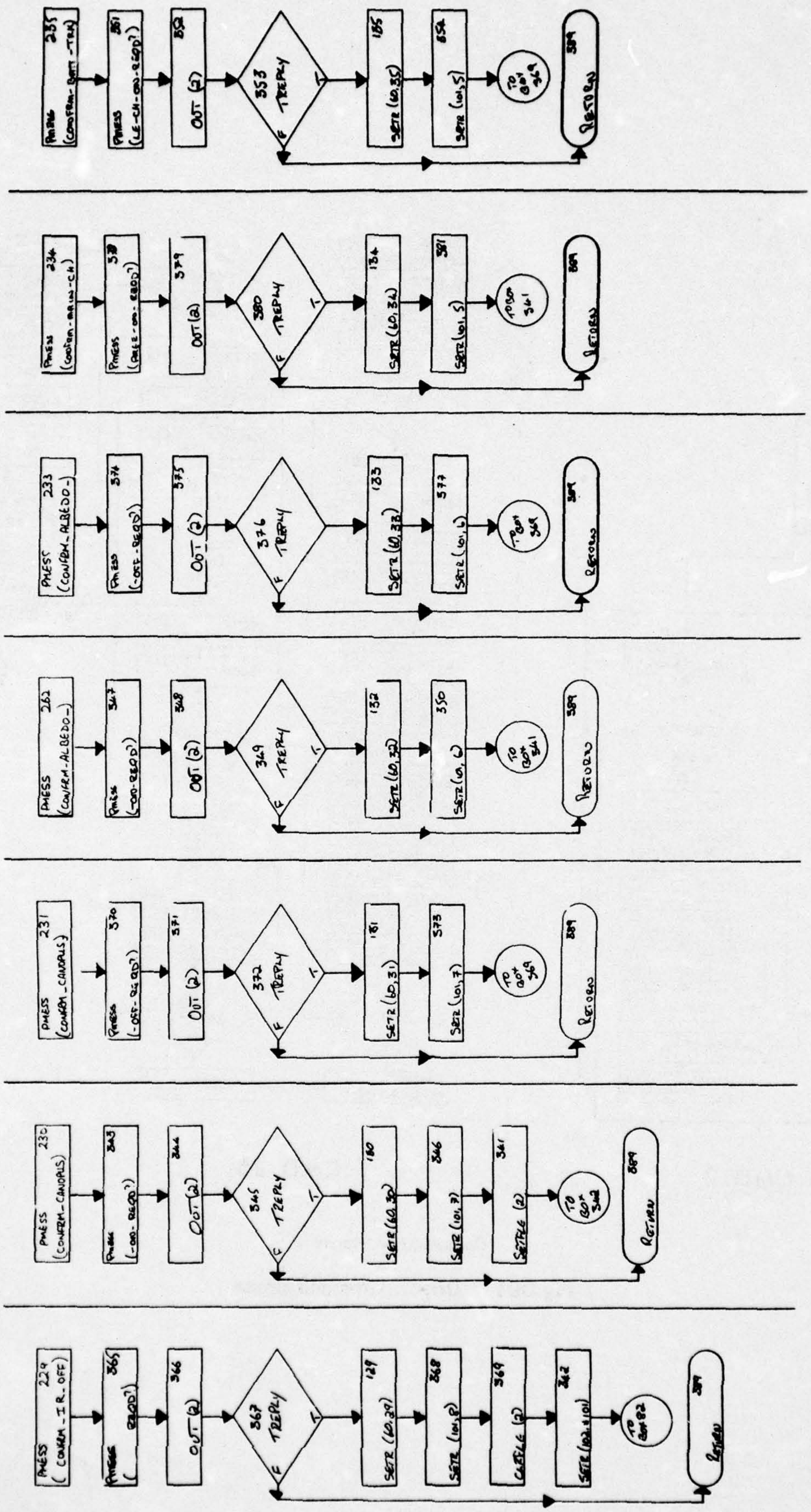
Fig.D60 Direct command phase



Command and verify

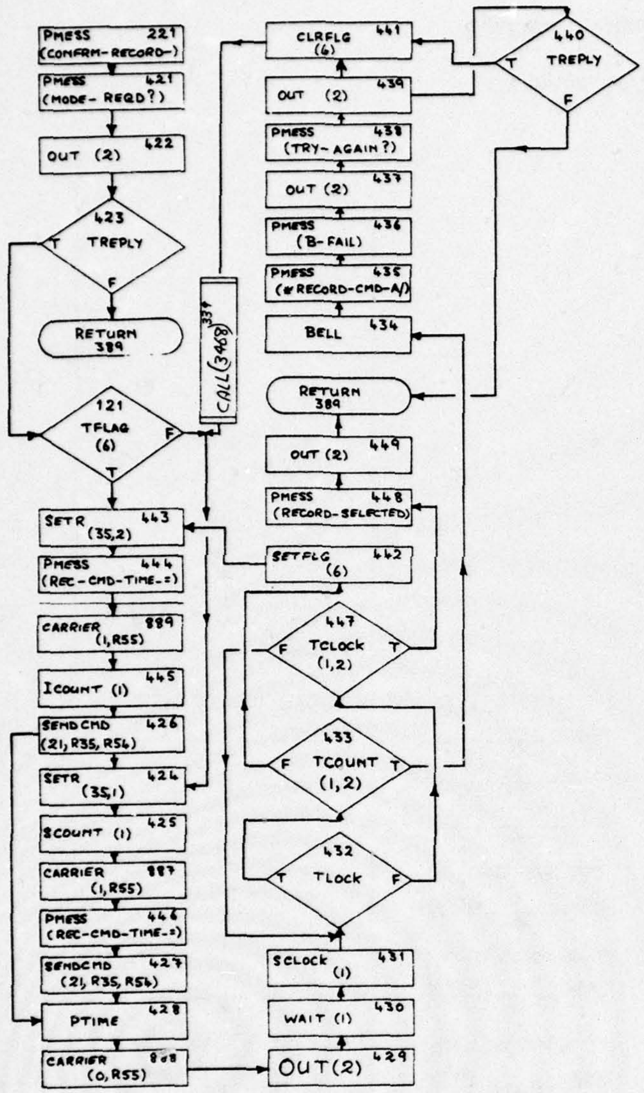
Fig.D61 Direct command phase

Fig.D62



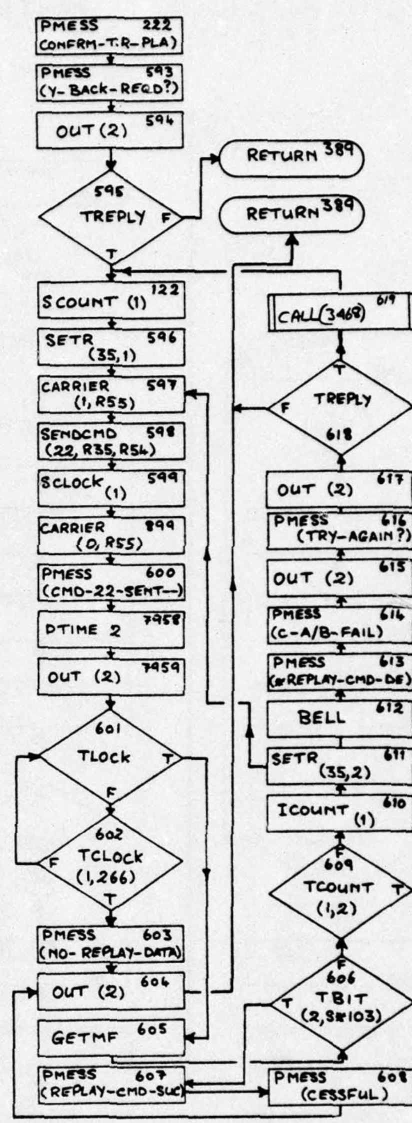
Commands 29 to 35

Fig.D62 Direct command phase



Record

CMD21

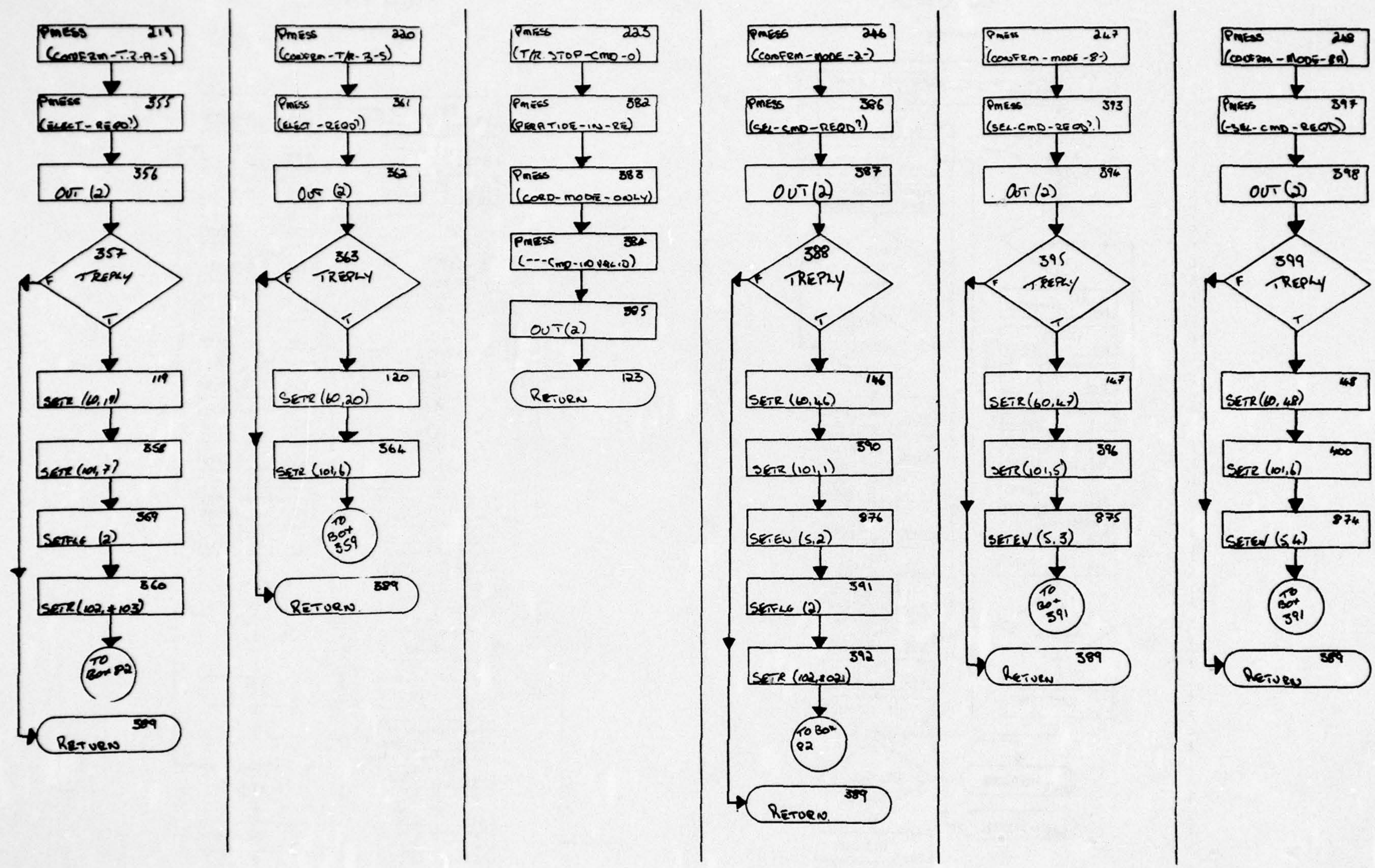


Replay

CMD 22

Fig.D63 Direct command phase

Fig.D64



Commands 19, 20, 23, 46, 47 and 48

Fig.D64 Direct command phase

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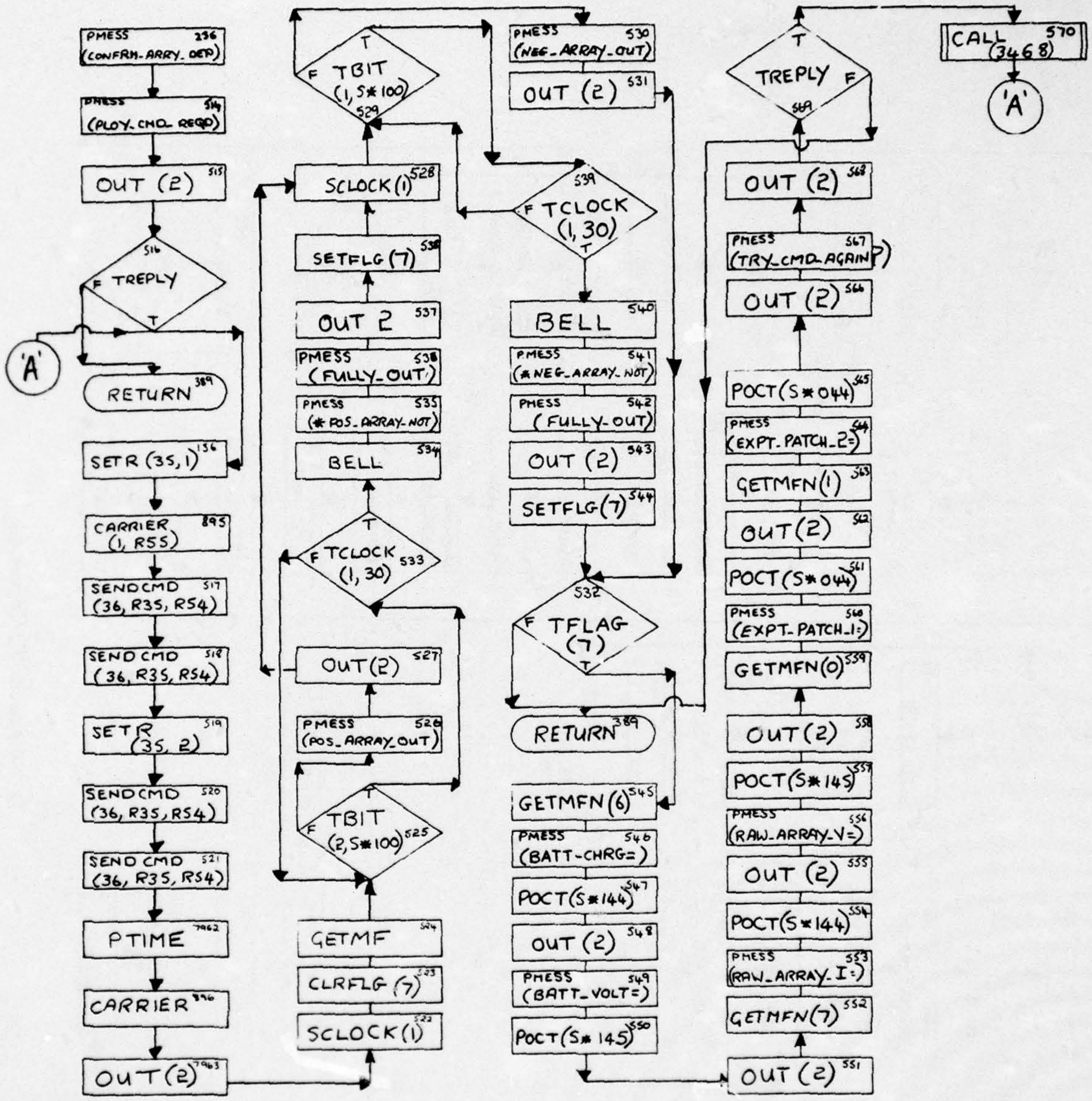

Command 36

Fig.D65 Direct command phase

AD-A032 212 ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) F/G 22/2
REAL TIME OPERATIONAL CONTROL OF MIRANDA.(U)
FEB 76 E A ANSTEY, M J HAMMOND
UNCLASSIFIED RAE-TR-76016 DRIC-BR-52227 NL

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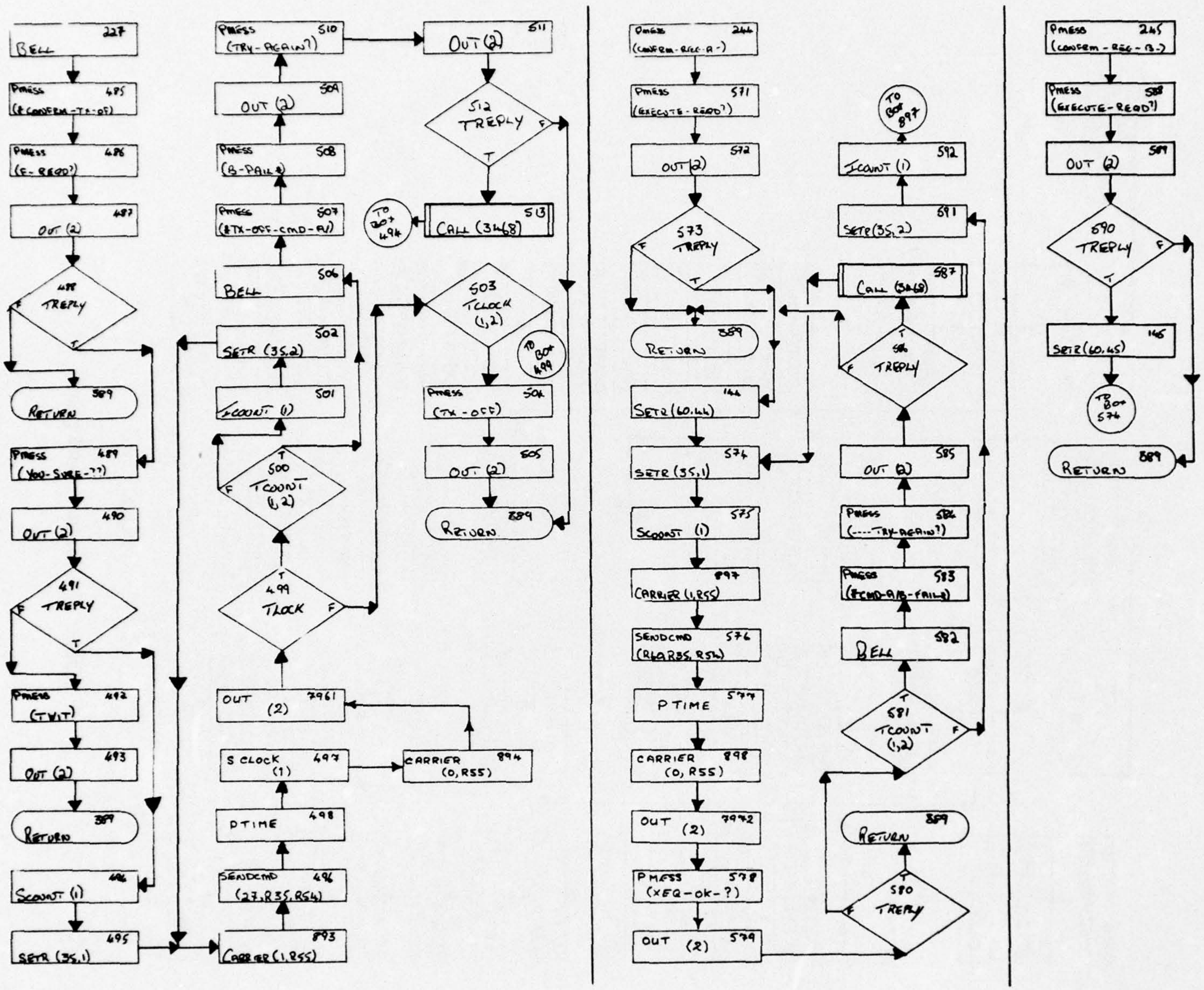
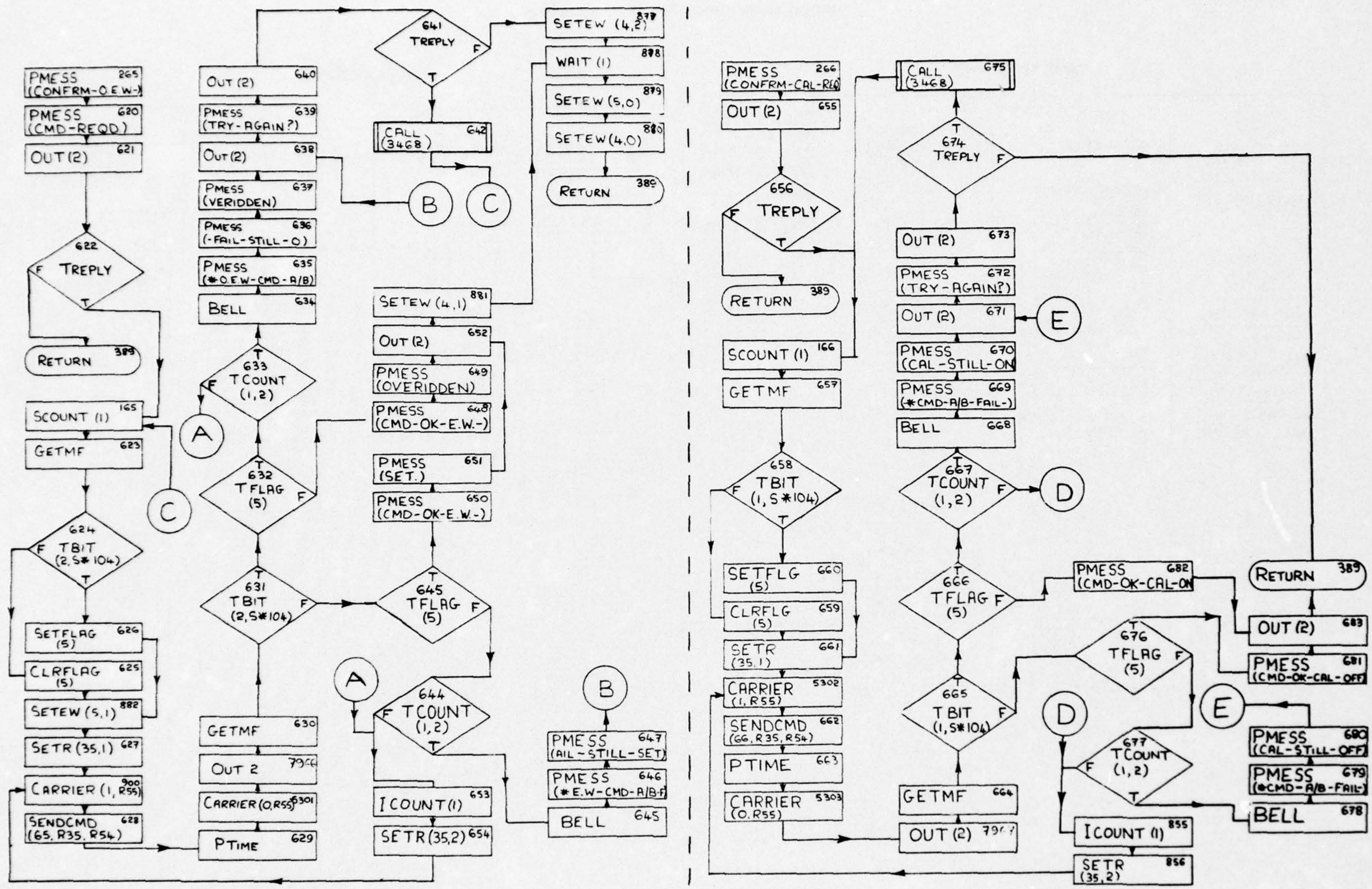
Fig.D66



Commands 27, 44 and 45

Fig.D66 Direct command phase



Command 65

Command 66

Fig.D67 Direct command phase

Fig.D67

Fig.D68

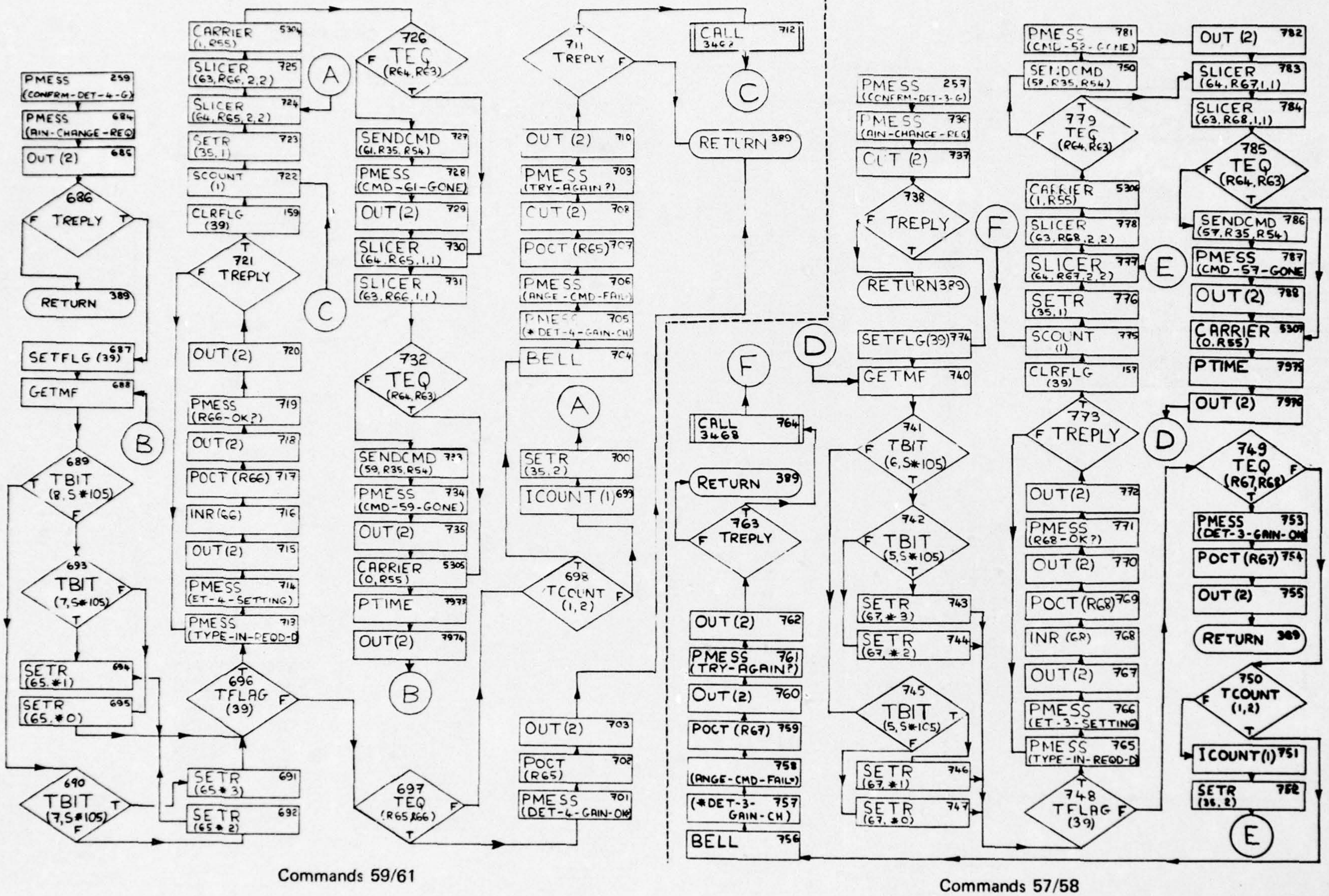


Fig.D68 Direct command phase

TR 76016

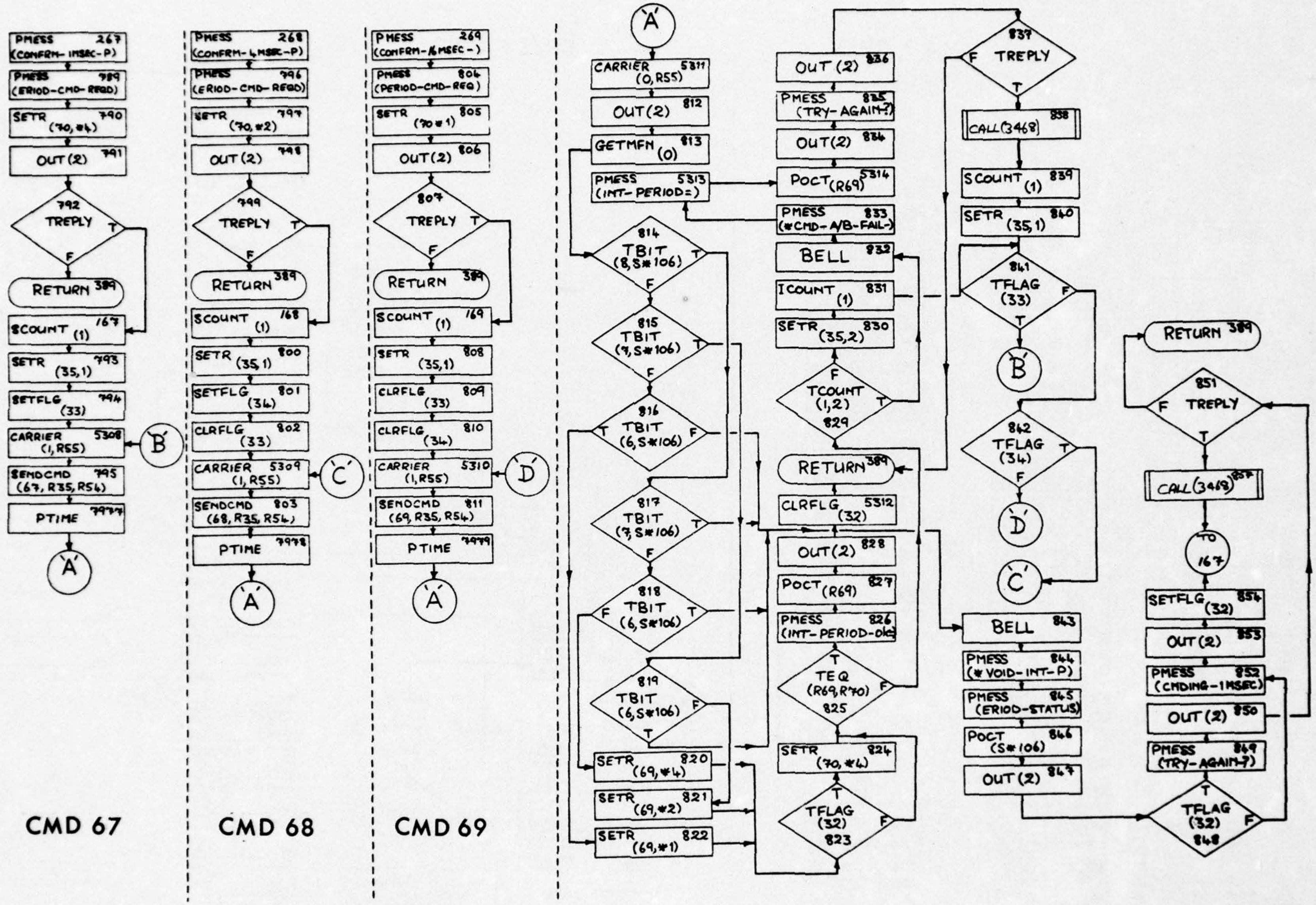


Fig.D69 Direct command phase

Fig.D69

Fig.D70

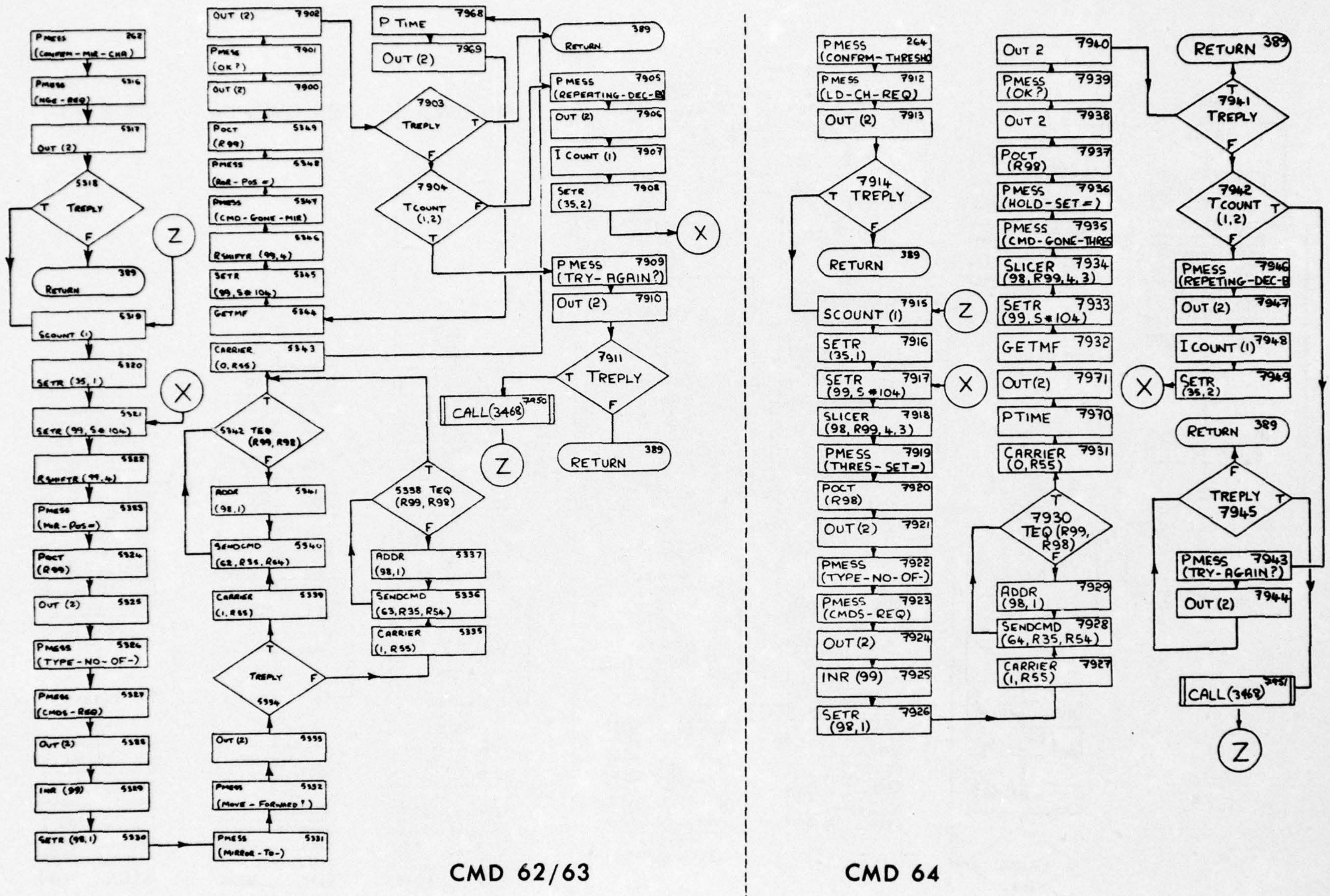


Fig.D70 Direct command phase

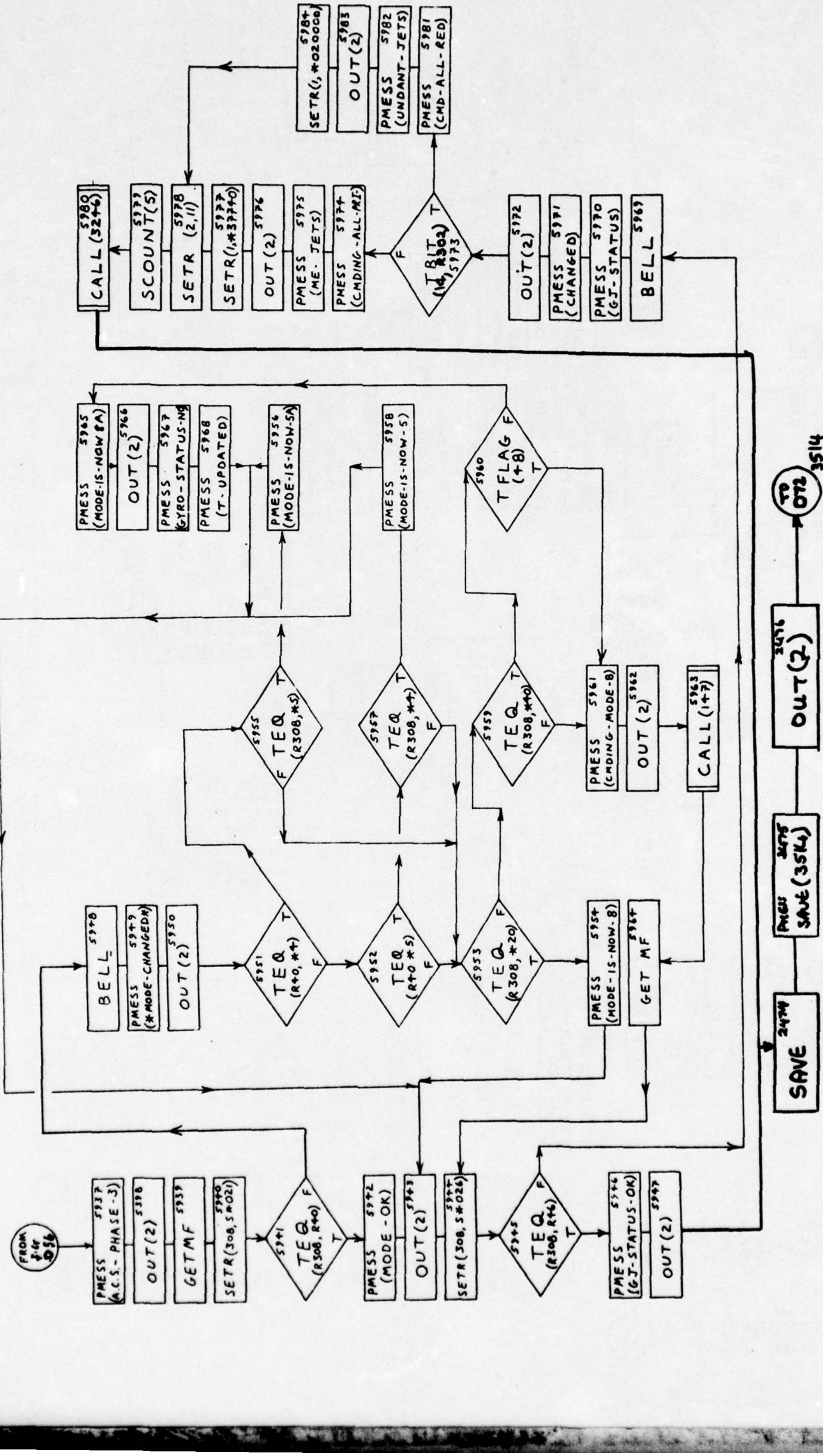


Fig.D71 ACS Phase 3

Fig.D72

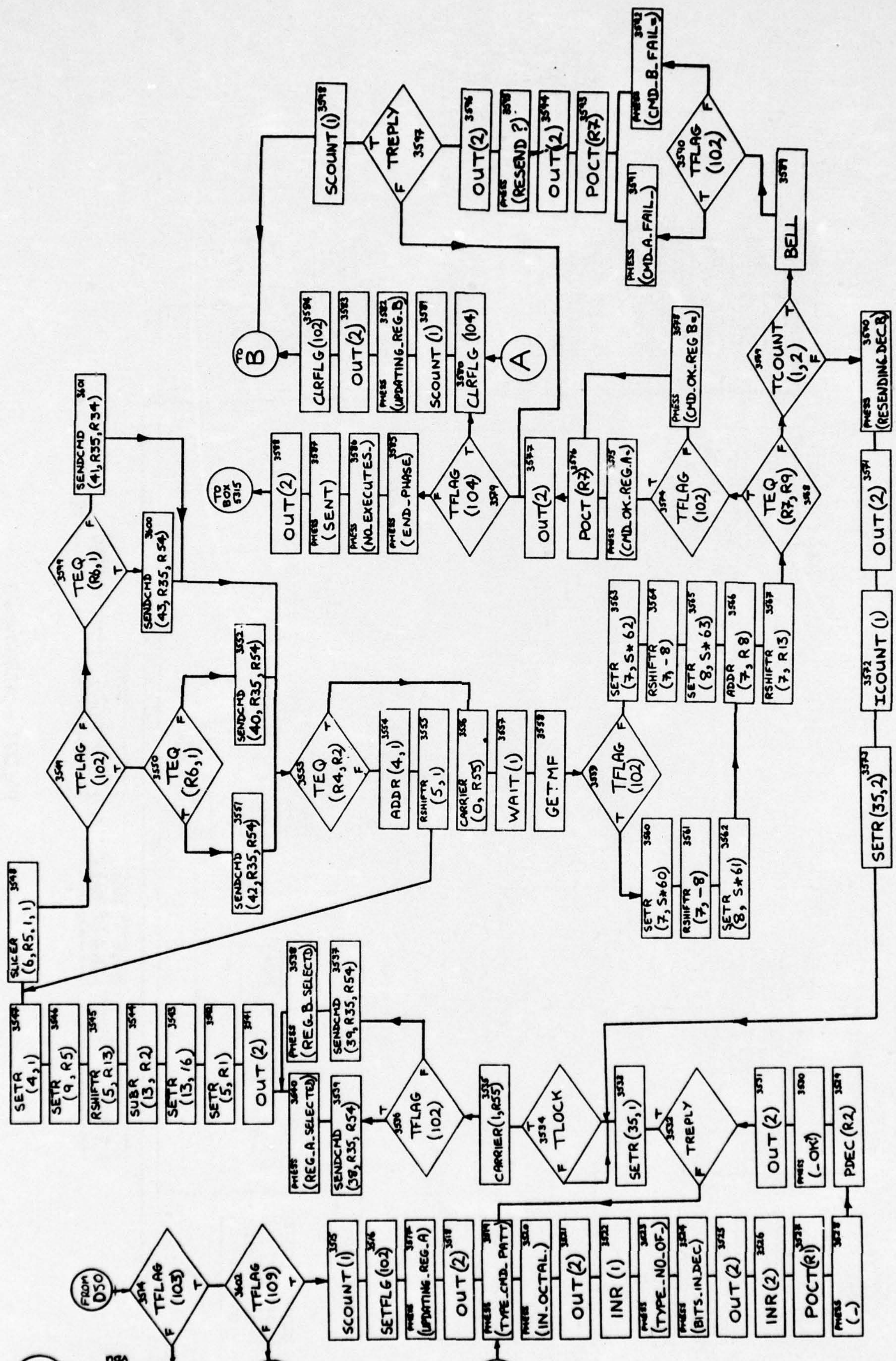


Fig.D72 Update regs. A and B

TR 76016

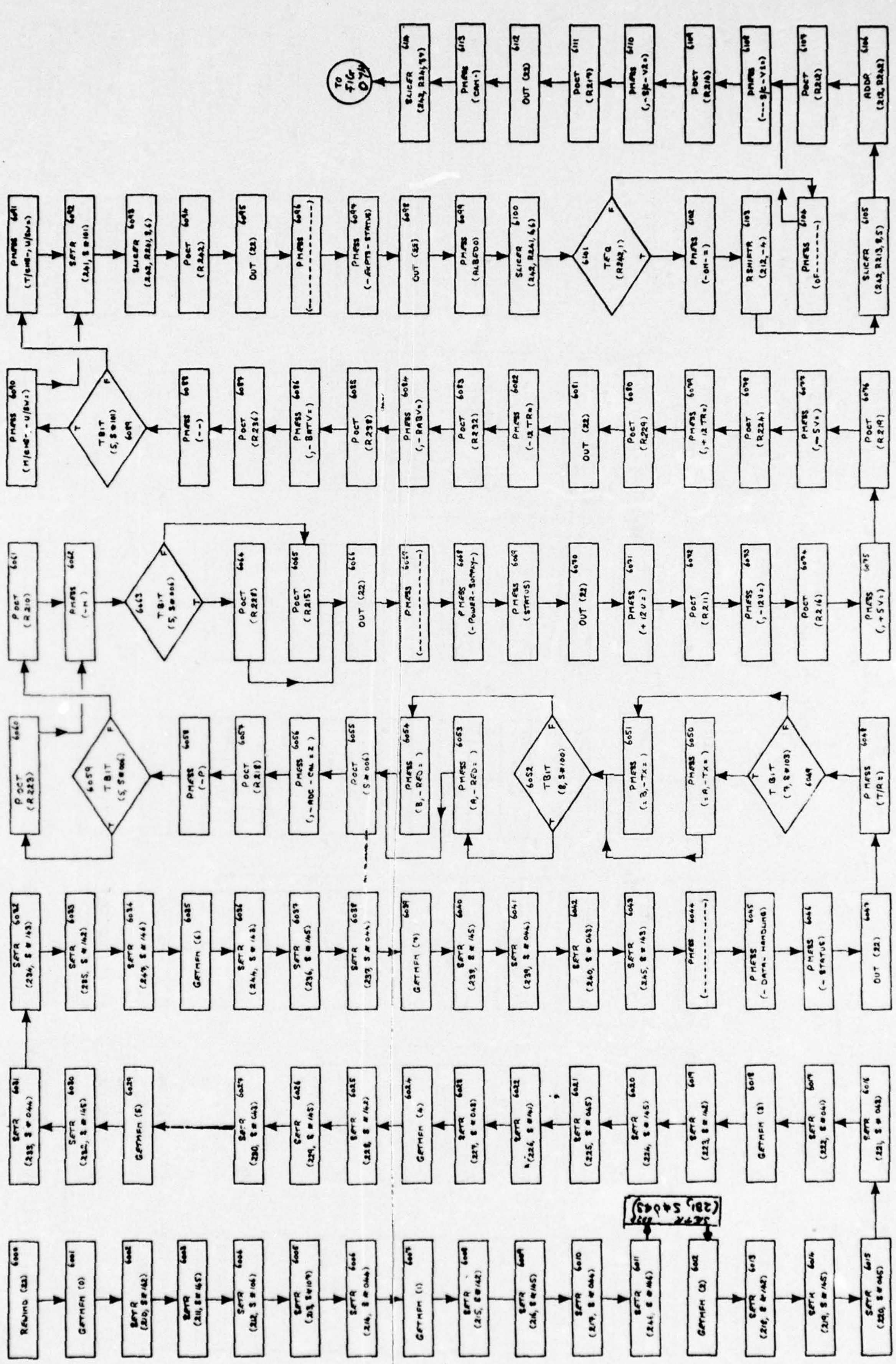


Fig.D73 VDU

Fig.D74

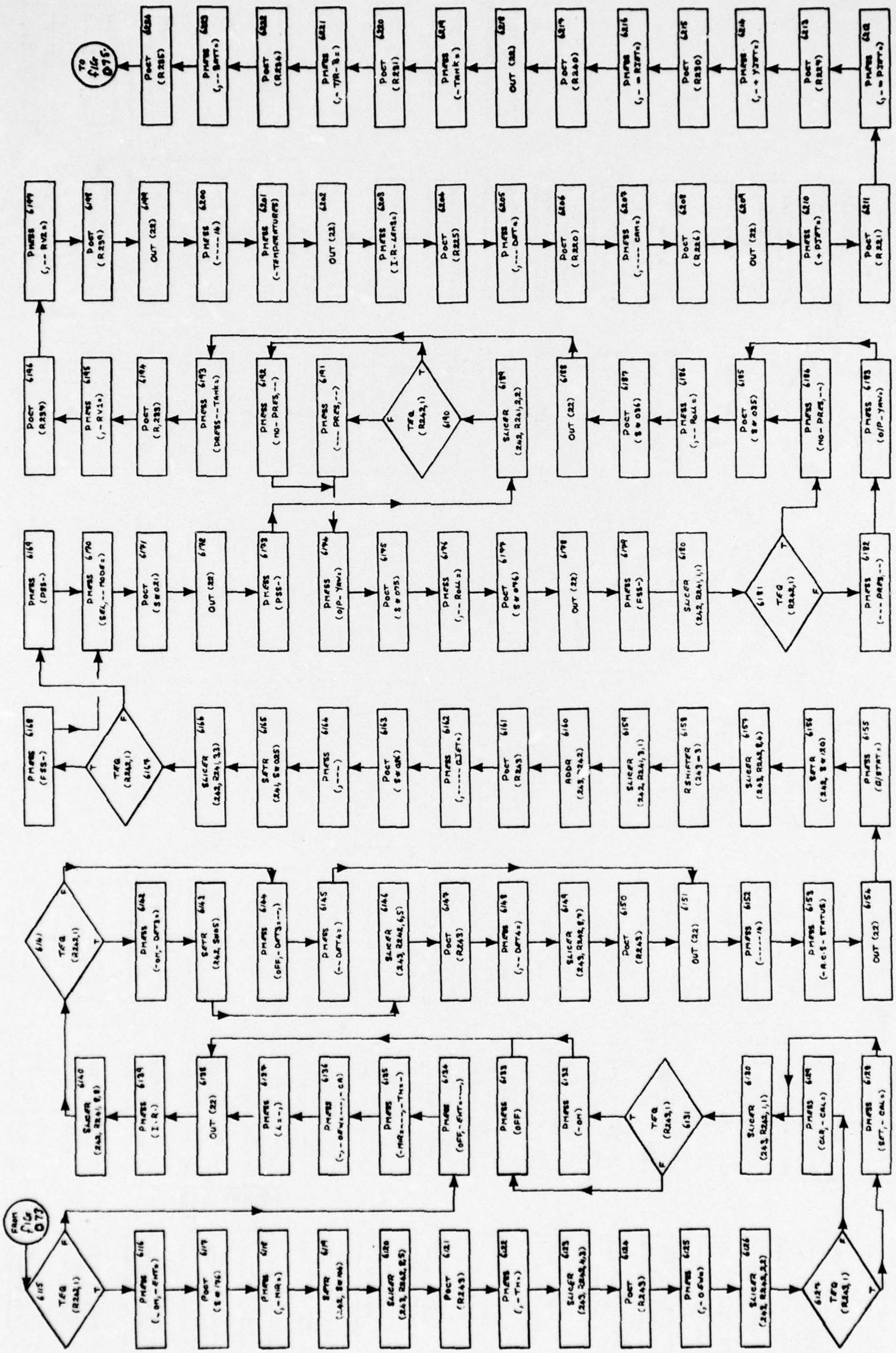
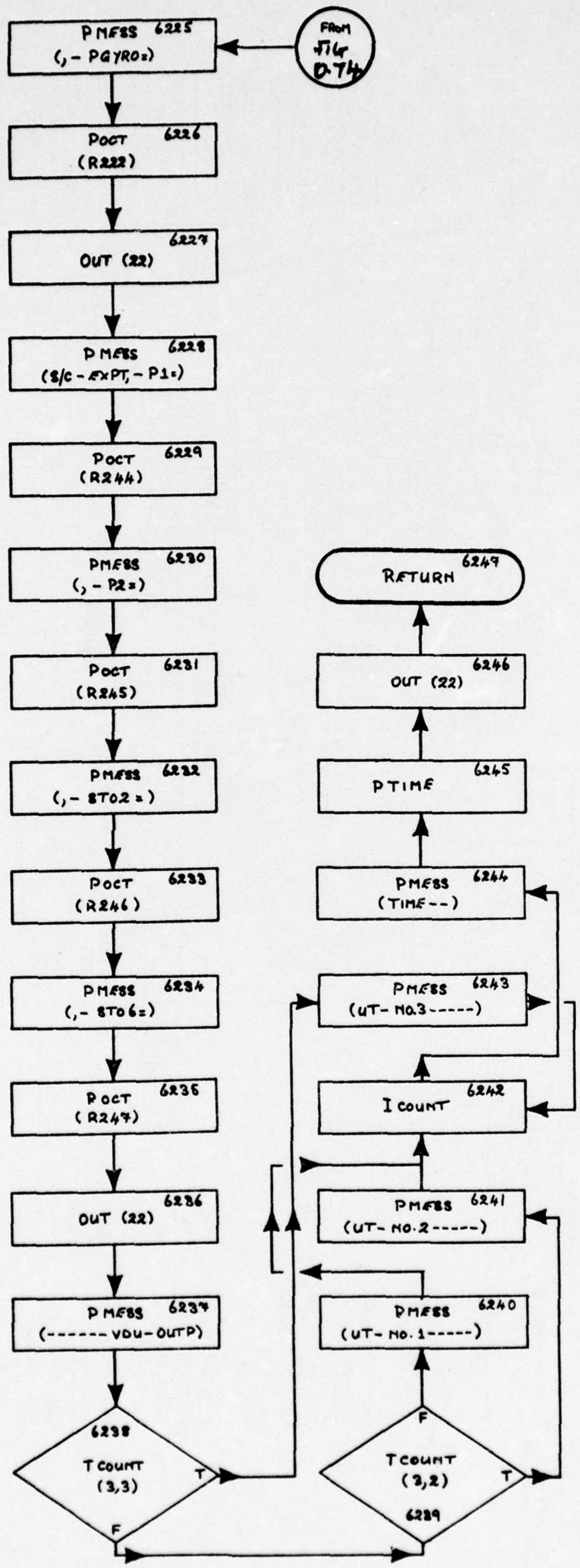


Fig.D74 VDU

TR 76016



TR 76016

Fig.D75 VDU

Fig.D76

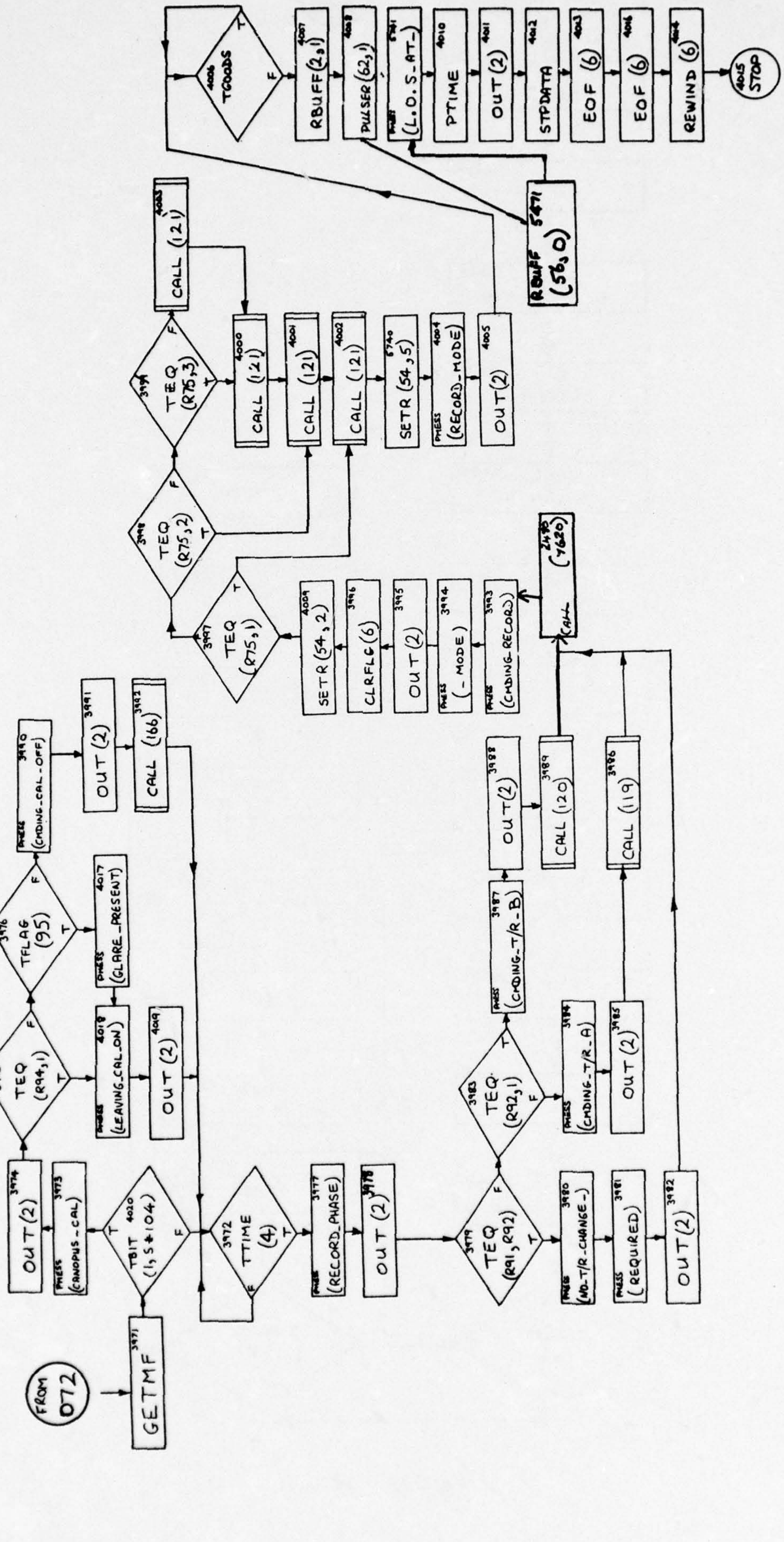


Fig.D76 LOS phase

TR 76016

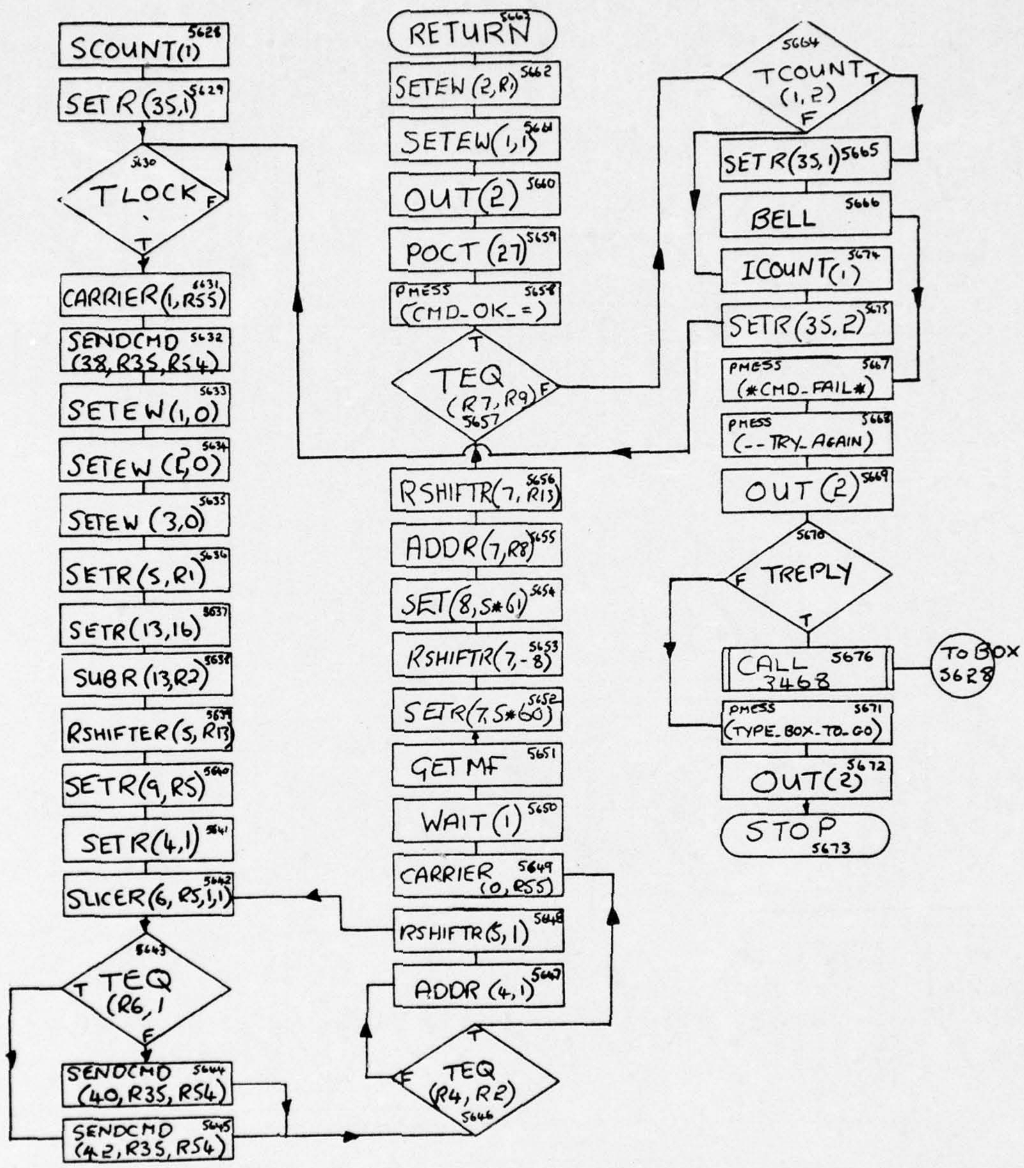


Fig.D77 Register 'A' load

TR 76016

Fig.D78

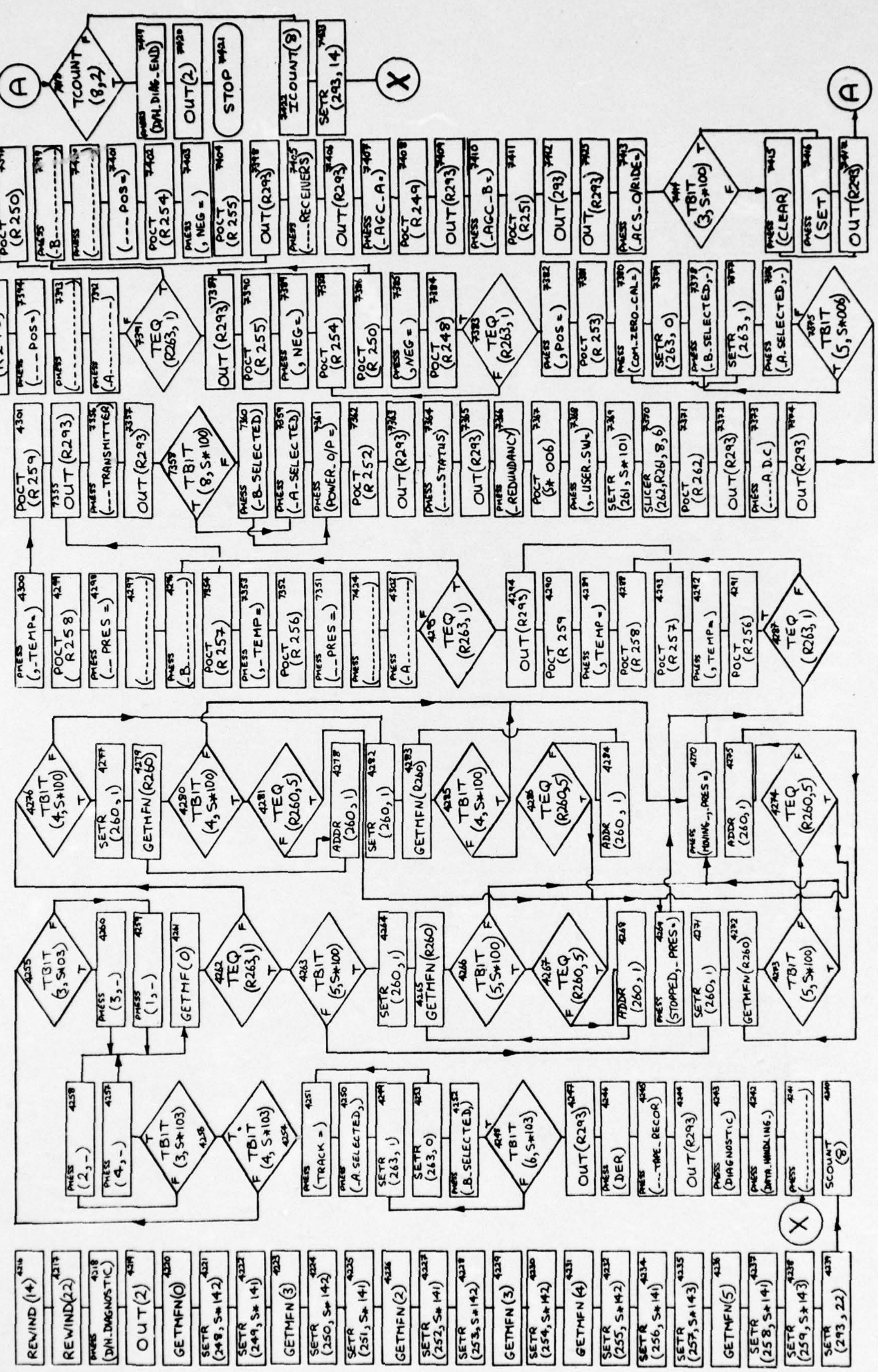


Fig.D78 D/H diagnostic

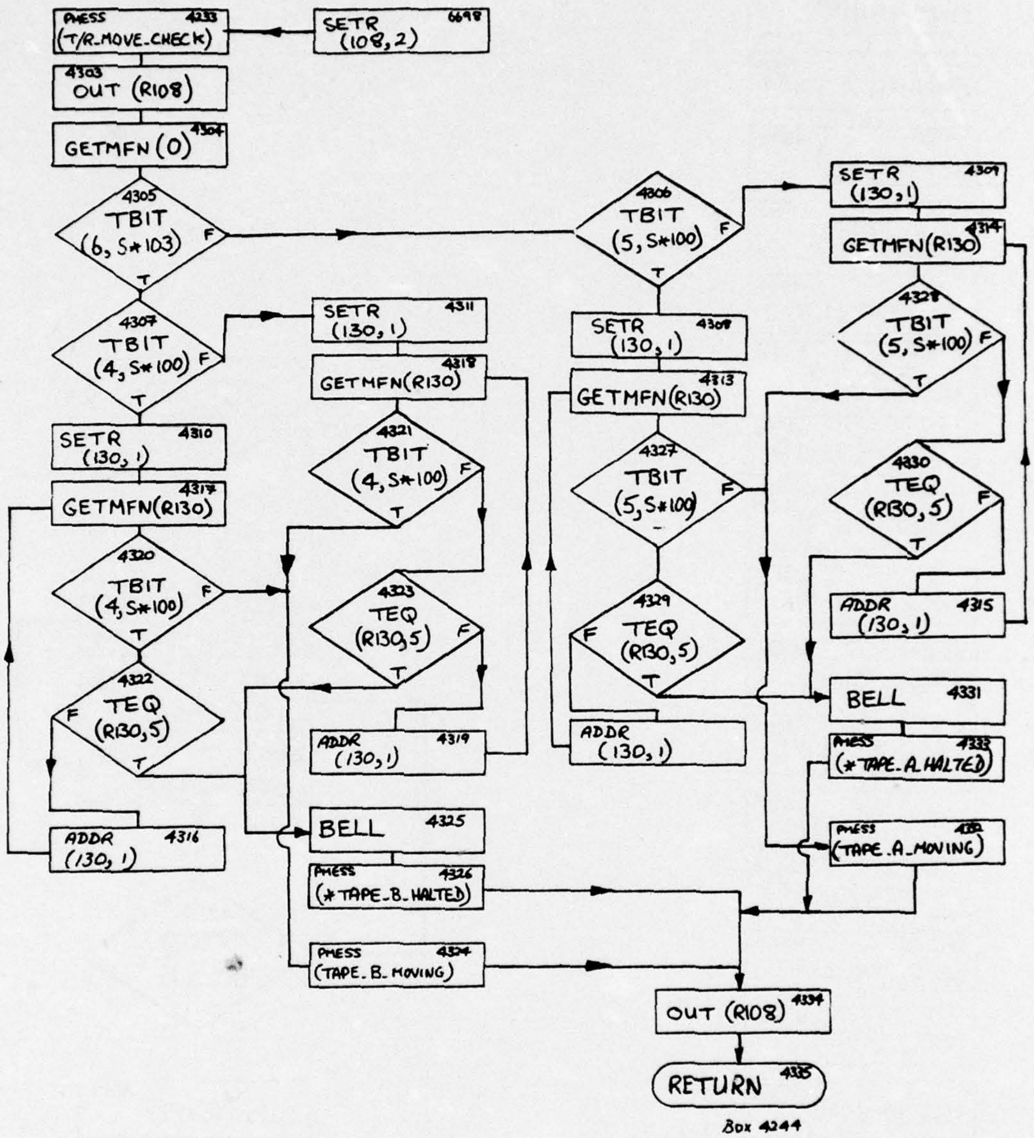


Fig.D79 Tape move check

TR 76016

Fig.D80

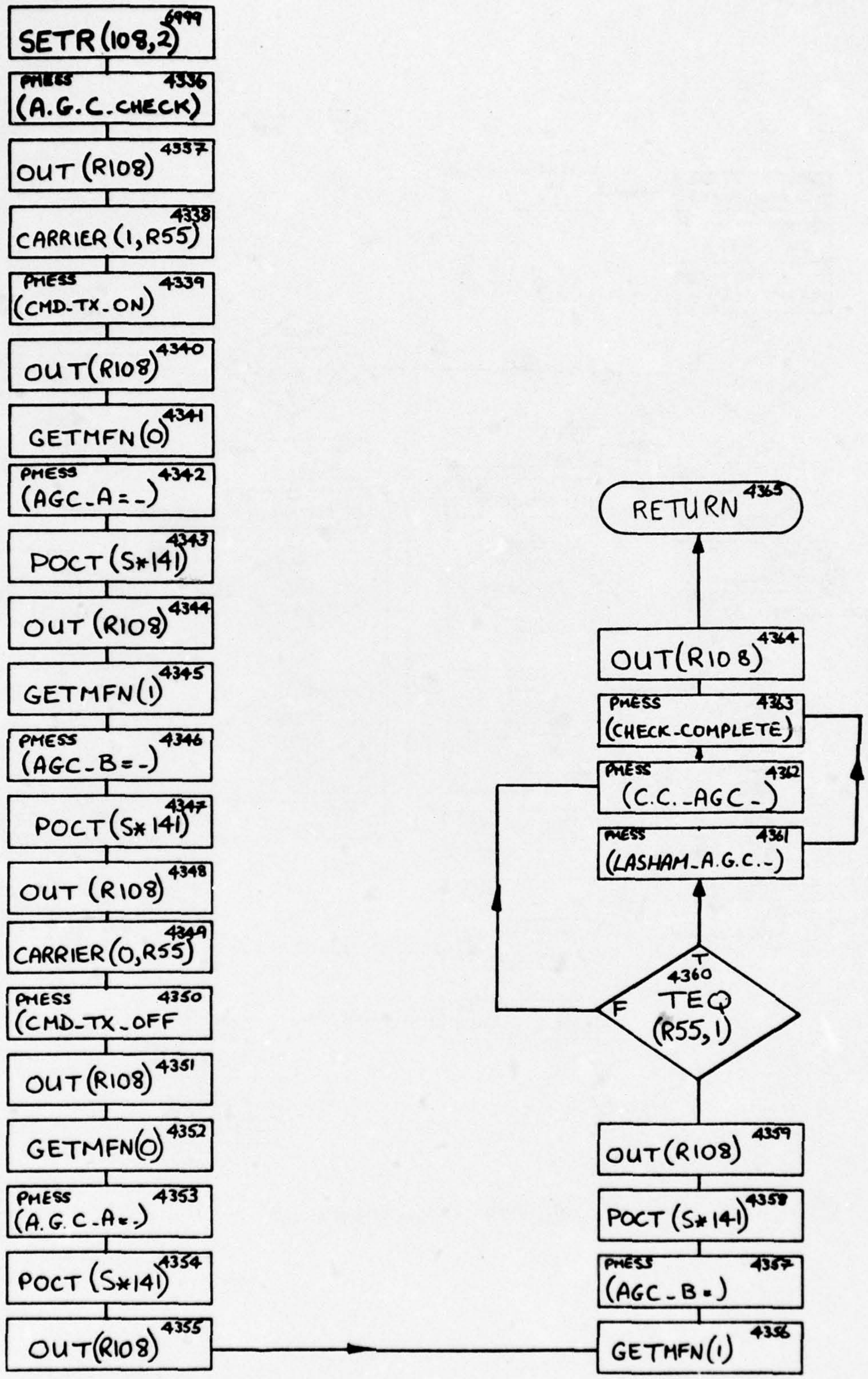


Fig.D80 AGC check

TR 76016

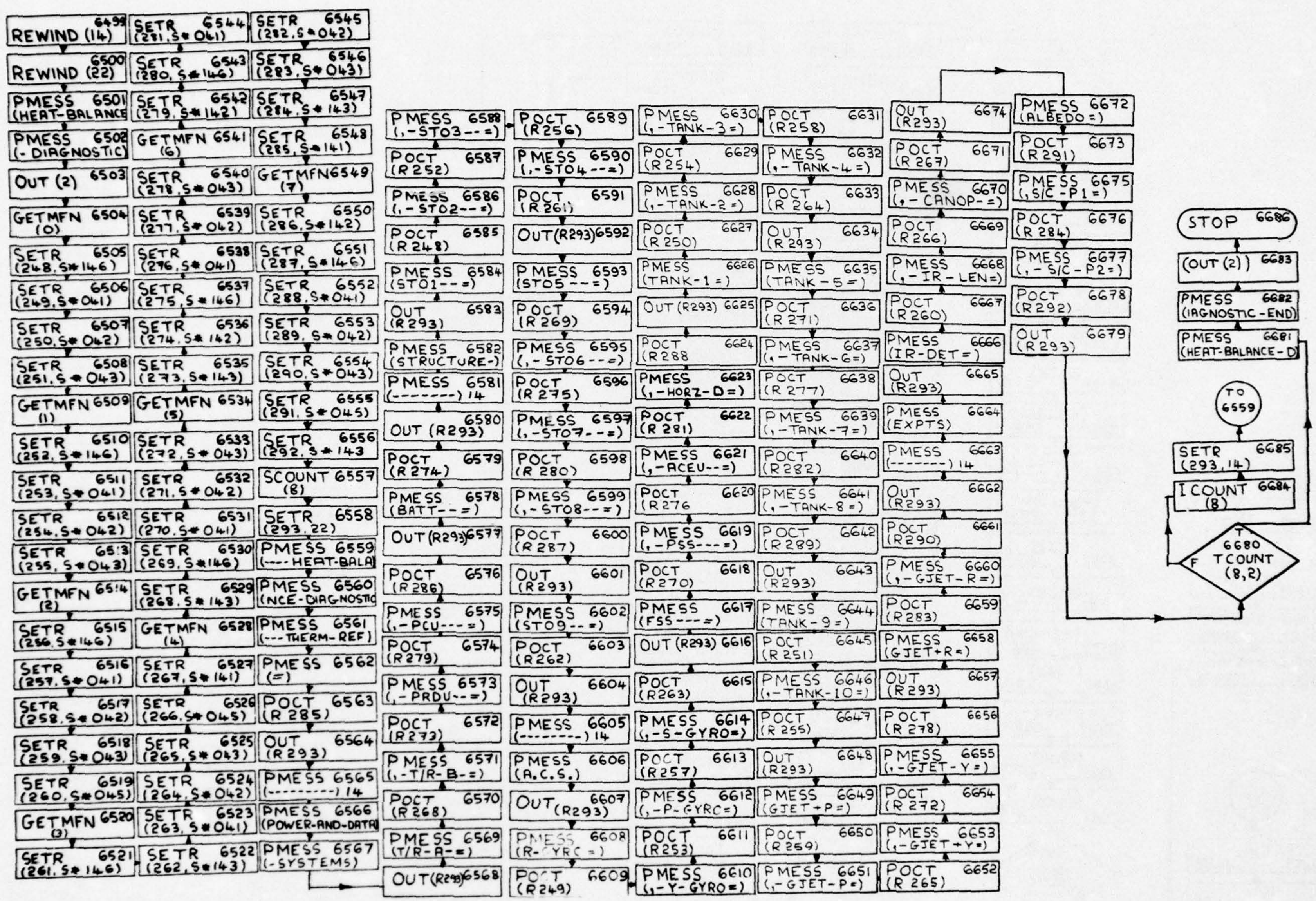


Fig.D81 Heat balance diagnostic

Fig.D82

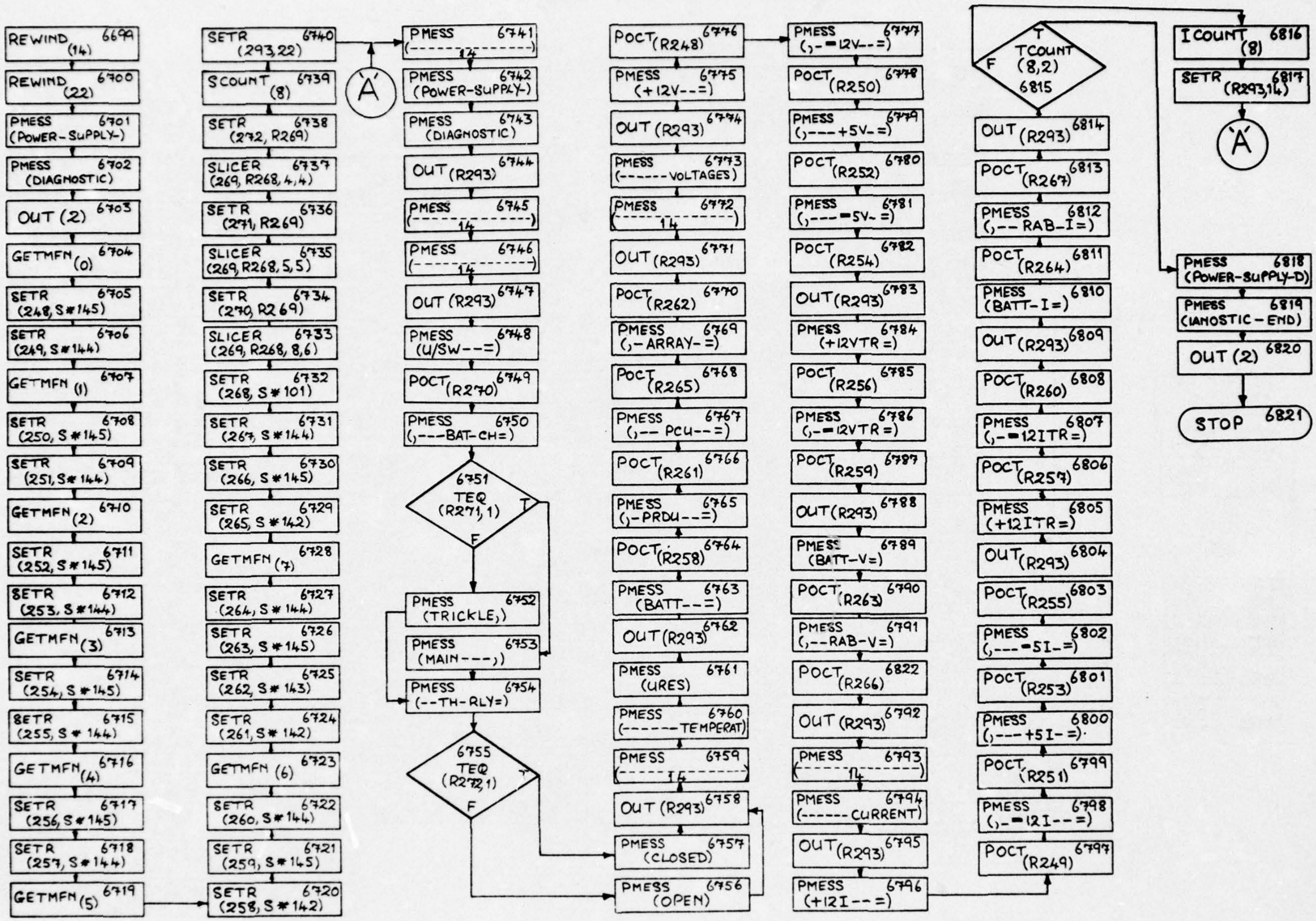


Fig.D82 Power supply diagnostic

TR 76016

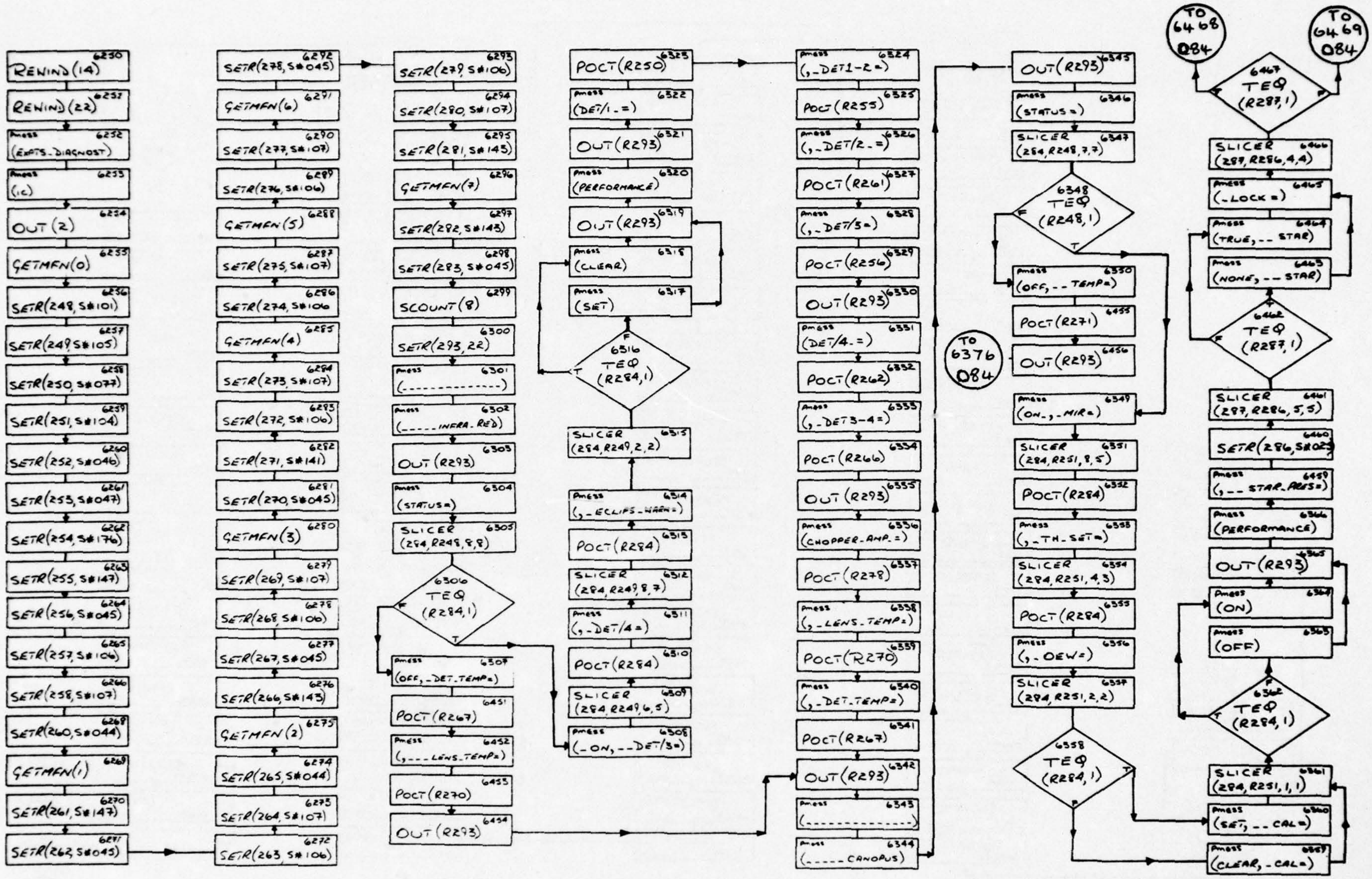


Fig.D83 Experiment diagnostic

Fig.D83

Fig.D84

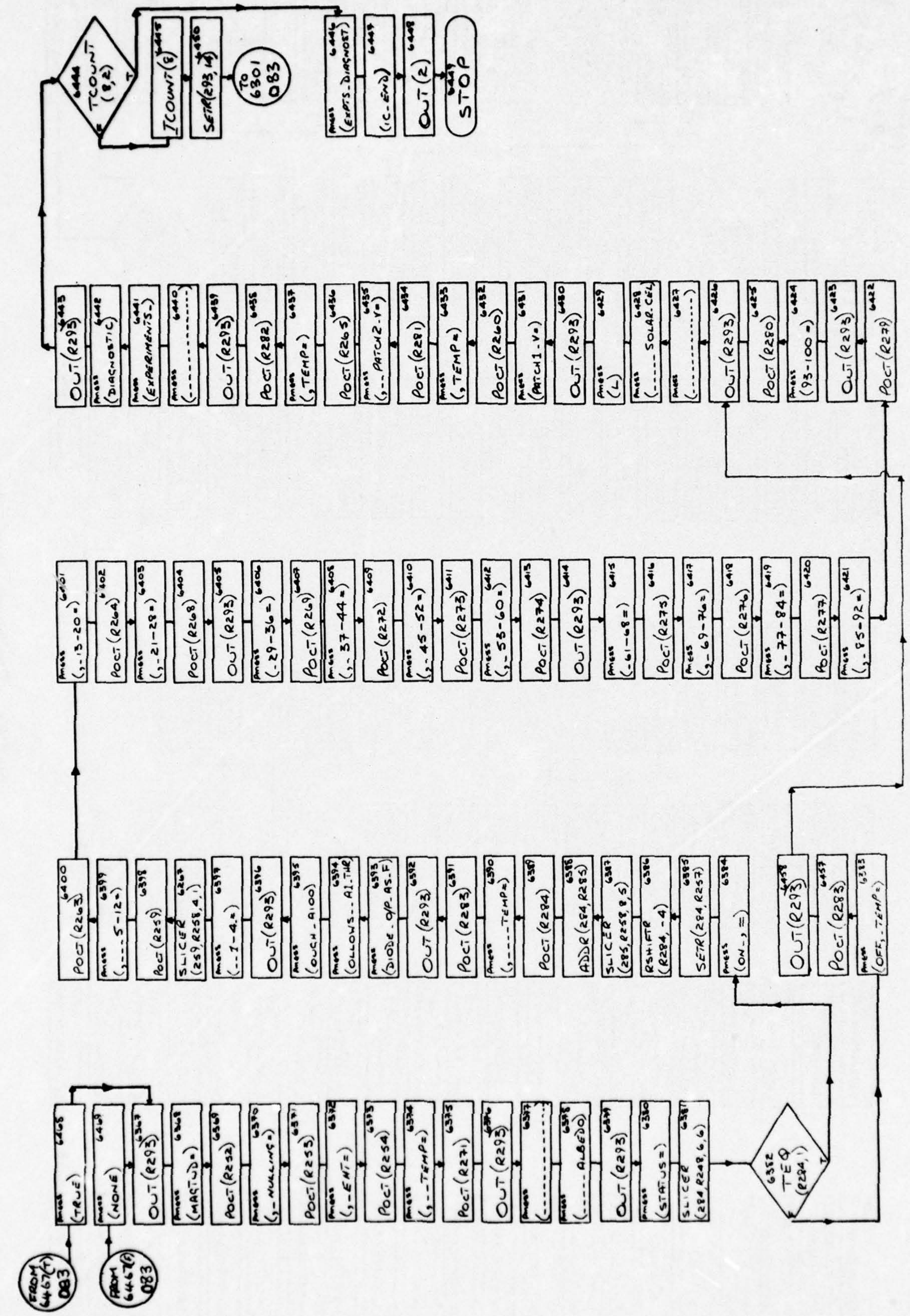


Fig.D84 Experiment diagnostic

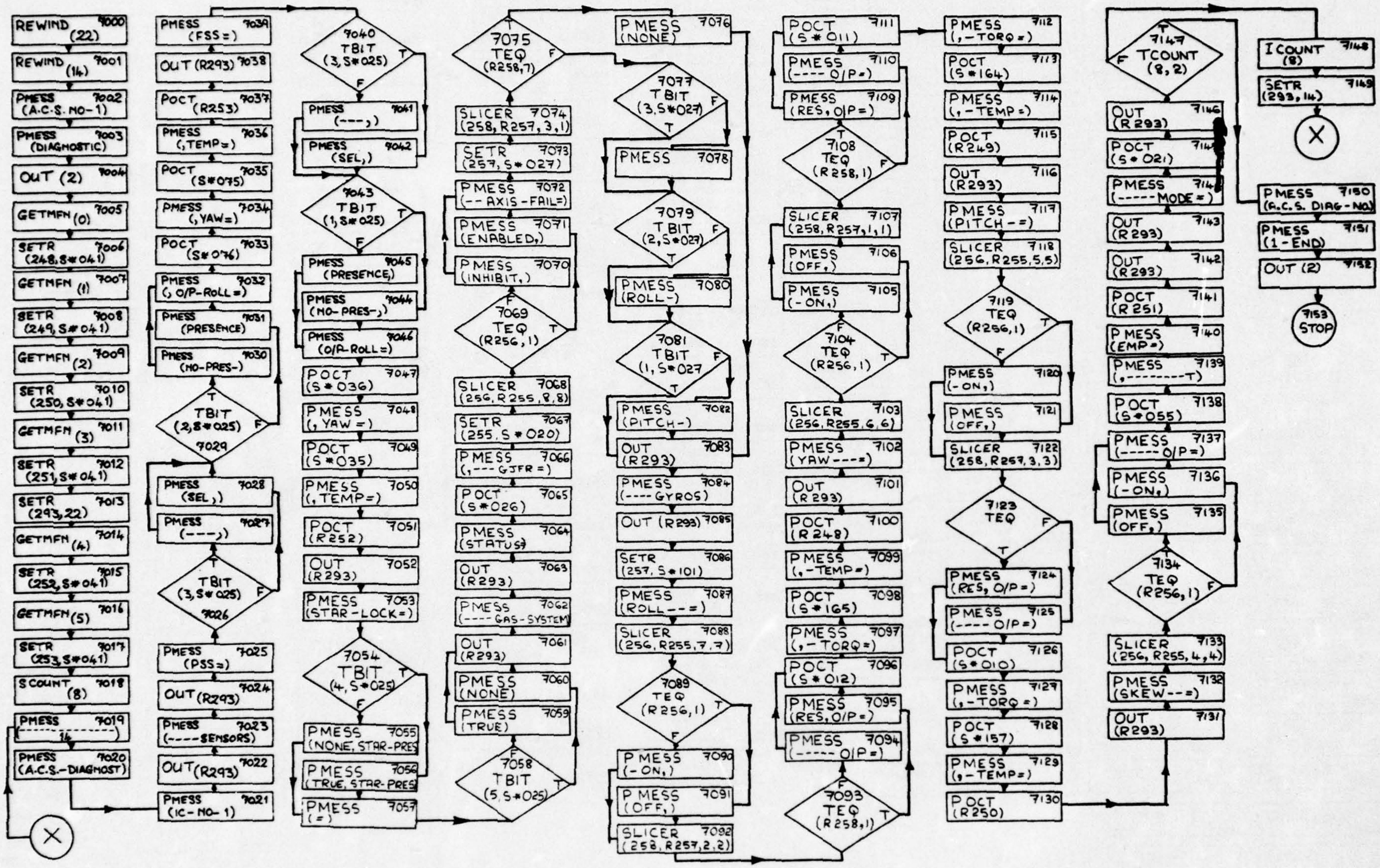


Fig.D85 ACS diagnostic number 1

Fig.D85

Fig.D86

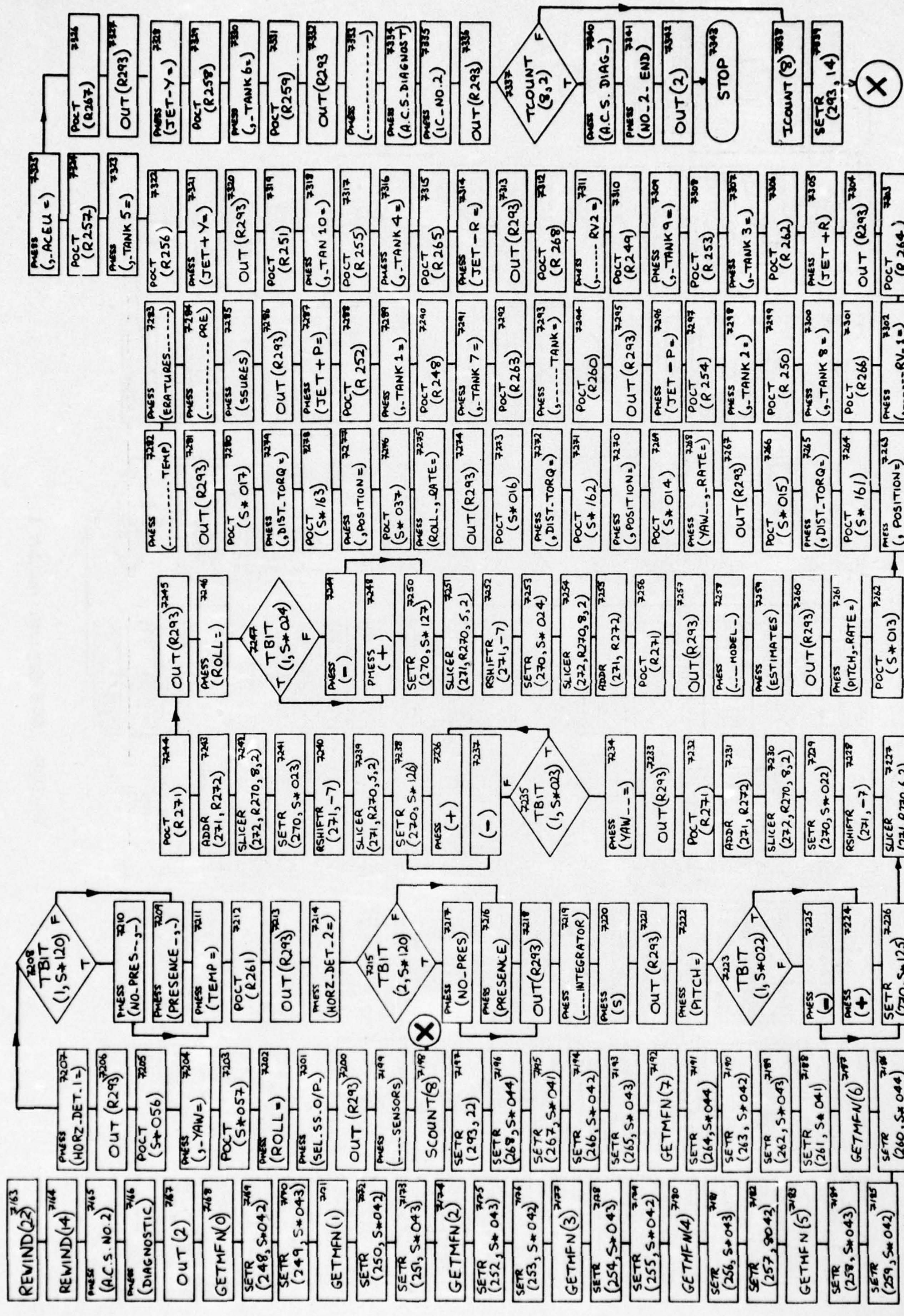


Fig.D86 ACS diagnostic number 2

TR 76016

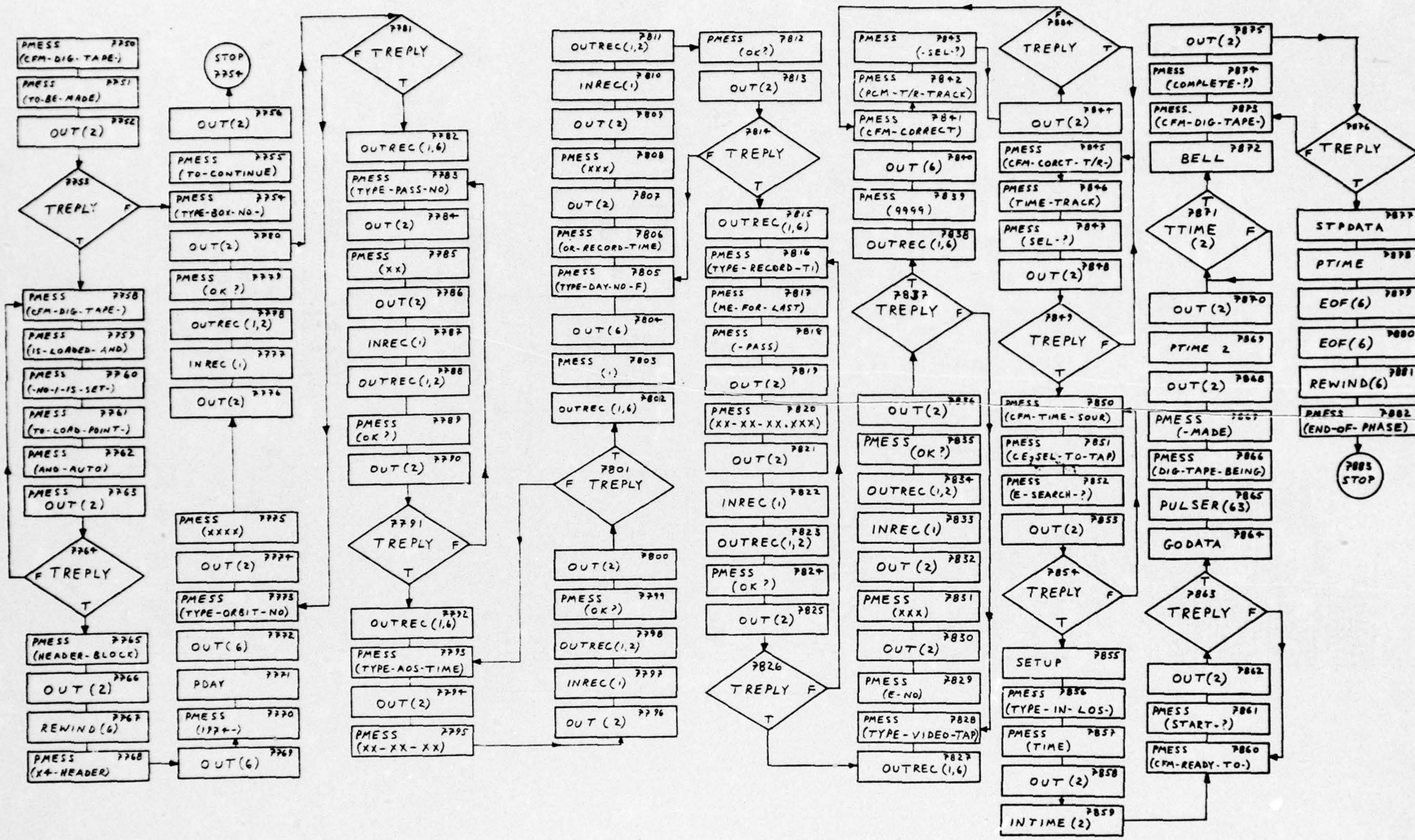


Fig.D87 Mag to dig tape

Fig.D87

Fig.D88

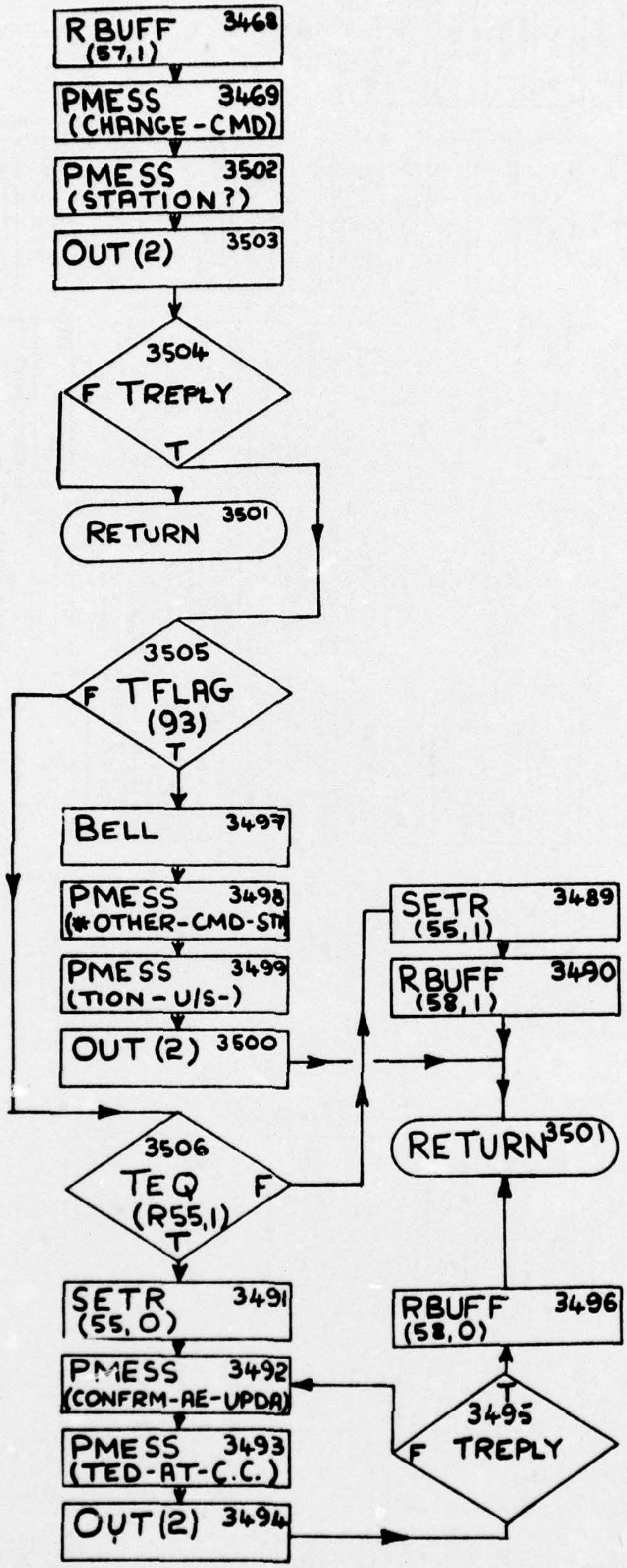


Fig.D88 Command station change

TR 76016

Flag Number	Initiating Phase	Action: True	Action: False	Flag Number	Initiating Phase	Action: True	Action: False
1	Multiple Commands	Register A commands	Register B commands	77	Set Up	Schedule Planned Commands	No Planned Commands Required
10	Set Up	ADC A Expected	ADC B Expected	81	TTY	Command Has Timed Execute	Execute is Not Timed
12	Set Up	Timer Check Scheduled	No Timer Check	82	Set Up	Command Has Timed Execute	Execute is Not Timed
14	Set Up	Schedule Canopus Switch on	No Canopus Switch On Required	84	Set Up	First Command is Timed	First Command is Not Timed
15	Data Handling	All User Switches Off	User Switch Status OK	85	Set Up	Second Command is Timed	Second Command is Not Timed
16	Set Up	O.E.W. Set	O.E.W. Inhibited	86	Set Up	Third Command is Timed	Third Command is Not Timed
17	Set Up	Mirror Change Required	No Mirror Change Required	87	Set Up	Schedule TTY commands	No TTY Commands Required
19	Set Up	Schedule I.R. Switch On	No I.R. Switch on Required	91	Set Up	Schedule Direct Commands	No Direct Commands Required
21	Set Up	Schedule Albedo Switch On	No Albedo Switch on Required	93	Set Up	Command Station Change Inhibited	Command Station Change Allowed
24	Set Up	Threshold Change Required	No Threshold Change Required	95	Canopus Assess	Glare Detected	No Glare Detected
25	Set Up	Schedule Star Lock Assessment	No Star Lock Assessment Required	103	Set Up	Schedule A.C.S. Register Set	No A.C.S. Register Set Required
30	Multiple Commands	No Execute Required	Execute Required	104	Set Up	Schedule Register B Set	No Register B Set Required
35	Set Up	First Pass Analysis	Not First Pass	105	Set Up	Schedule A.C.S. Register Check	No A.C.S. Register Check Required
36	Set Up	Schedule Detector 4 change	No Detector 4 change Required	106	Set Up	Schedule Register A check	No Register A Check Required
37	Set Up	Schedule Detector 3 change	No Detector 3 change Required	107	Set Up	Schedule Register B Check	No Register B check Required
38	Set Up	Schedule Integration Period Change	No Integration Period change Required	109	Set Up	Schedule Register A Set	No Register A Set Required
40	Set Up	Transmitter A Expected	Transmitter B Expected	114	Multiple Commands	Gas Jet Status Changed	Not A Gas Jet Status Command
48	Set Up	Skew Gyro Available	Skew Gyro in use	115	Multiple Commands	Mode Status Changed	Not A Mode Status Command.
49	Set Up	Schedule Replay	No Replay Required				
57	Replay	First Replay Command	Not A Replay Command.				
58	Replay	Second Replay Command	Not A Replay Command				
71	Set Up	Replay Commands Required	No Replay Commands Required				
72	Set Up	Only One Replay Command	Two Replay Commands Required				
75	Replay	Two Commands Sent	One Command Sent				
76	Replay	Commands Sent in Replay	No Commands Sent in Replay.				

Fig.D.89 Flags

Fig.D90

R1	MULT CMD ϕ, ACS ASSESS. REG UPDATE	CONTAINS MULT. CMD PATTERN TO BE SENT/LAST SENT. (16 BITS)
R2	—″—	CONTAINS NO. OF BITS IN PATTERN (STORED IN R1) TO BE SENT
R3	'RPLY' MULT CMD ϕ	AS R#1 BUT SPECIFIC TO ACS REG. B WHEN SENT IN REPLAY
R4	MULT CMD ϕ	CONTAINS AT ANY INSTANT, THE NO. OF BITS OF CMD PATTERN SENT.
R5	—″—	CONTAINS CONTENTS OF R1. THE LSB IS RIGHT SHIFTED AS PATTERN IS SENT.
R6	—″—	CONTAINS THE CURRENT L.S.B CMD. BIT TO BE SENT. IE CONTAINS EITHER A LOGIC '1' OR '0'.
R7	MULT. CMD ϕ, 'RPLY' MULT PATT. VERIFY	CONTAINS THE TELE. CONTENTS OF EITHER CMD REG A OR B.
R8	—″—	CONTAINS 8LSB OF EITHER CMD REG. A OR B. USED TO PRODUCE FINAL CONTENTS OF R7.
R9	MULT CMD ϕ	CONTAINS THE ACTUAL CMD PATTERN TO BE SENT. (DONT-CARE BITS REMOVED).
R10	CMD PATTERN VERIFY ϕ	INTERNAL MANIPULATION.
R11	—″—	CMD PATTERN RECEIVED.
R12	—″—	CMD PATTERN SENT.
R13	MULT. CMD. ϕ	CONTAINS THE NO. (16 - CONTENTS OF R2) IE. NO. OF 'DONT-CARE' BITS IN PATTERN.
R14	CMD VERIFY ϕ	INTERNAL USE
R15	GAS JET EXERCISE #1	CONTAINS NO. OF CYCLES REQ.
R16		
R17		
R18	ACTUAL VERIFY ϕ	SPECIFIES IF 'LO' PWR. GYRO CMD TO BE SENT.
R19	'RPLY' MULT. CMD ϕ	CONTAINS ACTUAL PATTERN TO BE SENT.
R20	SETUP ϕ PLANNED CMD ϕ.	CONTAINS PATTERN OF 1ST MULT CMD. TO BE SENT (16 BITS)
R21	—″—	CONTAINS NO. OF BITS OF PATTERN TO BE SENT.
R22	—″—	AS REG #20 BUT FOR 2ND CMD TO BE SENT.
R23	—″—	AS REG #21 BUT FOR 2ND CMD TO BE SENT.
R24	—″—	AS REG #20 BUT FOR 3RD CMD TO BE SENT.
R25	—″—	AS REG #21 BUT FOR 3RD CMD TO BE SENT

R26	SET-UP ϕ	CONTAINS EXPECTED D.H RED. STATUS
R27	DH-PS EVAL.	CONTAINS ACTUAL D.H RED STATUS
R28	SET-UP ϕ	CONTAINS EXPECTED USER SWITCH STATUS
R29	DH-PS EVAL	CONTAINS CONTENTS OF TELE SYLL. OF USER SWITCH STATUS.
R30	DH-PS EVAL	CONTAINS ACTUAL USER SWITCH STATUS (5 BITS)
R31	DH-PS EVAL	CONTAINS EXPECTED IR STATUS.
R32	—″—	CONTAINS EXPECTED CANOPUS STATUS
R33	—″—	CONTAINS EXPECTED ALBEDO STATUS
R34	—″—	CONTAINS ACTUAL IR STATUS
R35	MULT. CMD ϕ ET AL	CONTENTS SPECIFY DECODER A OR B FOR CMD
R36	SET UP ϕ	SETS UP COUNTDOWN CLOCK TO SPECIFIED PASS DURATION IN MINUTES.
R37	—″—	
R38	—″—	
R39	—″—	
R40	—″—	CONTAINS EXPECTED MODE PATTERN.
R41	—″—	
R42	—″—	CONTAINS EXPECTED SUN SENSOR STATUS.
R43	—″—	CONTAINS EXPECTED GYRO STATUS.
R44	ACS EVAL	CONTAINS ACTUAL GYRO STATUS BITS
R45	—″—	CONTAINS GYRO STATUS SYL. CONTENTS/ ACTUAL GASJET STATUS.
R46	SET UP ϕ	CONTAINS EXPECTED GAS JET STATUS.
R47	ACS EVAL	BIT MANIPULATION IN GAS JET STATUS EVALUATION.
R48	SET UP ϕ	EXPECTED STATUS OF T-R STOP OVERRIDE BIT.

R49	DET. OF VERIFY ϕ.	DETERMINES ADDRESS BIT PATTERN WITH R#51
R50	—″—	CONTAINS MULT. CMD PATTERN. (EQUAL TO R1).
R51	—″—	DETERMINES ADDRESS BIT PATTERN.
R52	MULT. CMD EXECUTE ϕ	CONTAINS VALUE FROM TELE. OF PITCH TORQUING I PRIOR TO EXECUTE.
R53	—″—	CONTAINS VALUE FROM TELE OF PITCH TORQUING I AFTER EXECUTE.
R54	SET UP ϕ ET AL	SPECIFIES 5 OR 2 WORD CMD. FORMAT.
R55	—″—	SPECIFIES LASHAM OR C.C. AS CMD STATION.
R56	DH-PS EVAL.	CONTAINS ACTUAL STATUS OF CANOPUS USER SWITCH.
R57	—″—	CONTAINS ACTUAL STATUS OF ALBEDO USER SWITCH.
R58		
R59	GJ X #1	COMPARISON OF CORRECT NO. OF CYCLES REQ.
R60	DIRECT CMD ϕ	CONTAINS THE NUMBER OF THE CMD TO BE SENT.
R61		
R62		
R63	DIRECT CMD ϕ	IR GAIN SETTING (EXPECTED)
R64	DIRECT CMD ϕ	IR GAIN SETTING (ACTUAL).
R65	IR EVAL.	ACTUAL DET. 4 GAIN SETTING.
R66	SET UP ϕ	EXPECTED DET. 4 GAIN SETTING.
R67	IR EVAL.	ACTUAL DET. 3 GAIN SETTING.
R68	SET UP ϕ	EXPECTED DET. 3 GAIN SETTING.
R69	ALBEDO EVAL.	ACTUAL INTEG. PERIOD.
R70	SET UP ϕ	EXPECTED INTEG. PERIOD.
R71	ALBEDO EVAL	SPECIFIES WHICH INTEG. PERIOD TO CMD. AS REMEDIAL ACTION.
R72	DIRECT CMD ϕ	SPECIFIES TX SELECTED.
R73	'RPLY' MULT CMD. ϕ	SPECIFIES ACTUAL CMD. PATTERN SET INTO REG. A.

Fig.D90 Register Number 1

R74	RPLY MULT CMD φ	ACTUAL PATTERN IN REG. B.
R75	SET UP φ	SPECIFIES NO OF RECORD CMDS REQ.
R76	DH EVAL	CONTAINS NO. OF TRACK IN USE.
R77	STAR LOCK ASSESS (RPLY)	CONTAINS MF. COUNTER VALUE FOR PRES. SET.
R78	—‖—	CONTAINS MF. COUNTER VALUE FOR PRES. NOT SET.
R79	—‖—	CONTAINS MF. COUNTER VALUE FOR STAR LOCK TRIG SET.
R80	GJ EX # 2	CONTAINS SYLL REF. NO. OF DEMANDS. ALSO SPECIFIES JET REQ.
R81	—‖—	CONTAINS ACTUAL NO. OF DEMANDS.
R82	—‖—	CONTAINS ACTUAL JET IN USE.
R83	—‖—	SPECIFIES ACTUAL JET REQ.
R84	—‖—	SPECIFIES NO. OF JET PULSES REQ.
R85	SET UP φ	SPECIFIES LOGICAL UNIT NO.
R86	—‖—	SPECIFIES NEW THRESHOLD SETTING REQ.
R87	—‖—	SPECIFIES NEW MIRROR POSITION REQ.
R88	—‖—	PARAMETER LIMIT
R89	—‖—	PARAMETER LIMIT
R90	—‖—	SPECIFIES IF T.R. 'A' EXPECTED
R91	—‖—	SPECIFIES IF T.R. A REQ. NEXT PASS.
R92	DH EVAL	SPECIFIES ACTUAL T.R. SELECTED
R93	SET UP φ	SPECIFIES IF CAL EXPECTED TO BE ON.
R94	SET UP φ	SPECIFIES IF CAL TO REMAIN 'ON'
R95		
R96	SET UP φ	CONTAINS EXPECTED MIRROR POSTN
R97	—‖—	CONTAINS EXPECTED THRESHOLD SETTING
R98	DIRECT CMD φ	SPECIFIES WHEN NO. OF MIRROR POSTN. CMDS SENT IS CORRECT.

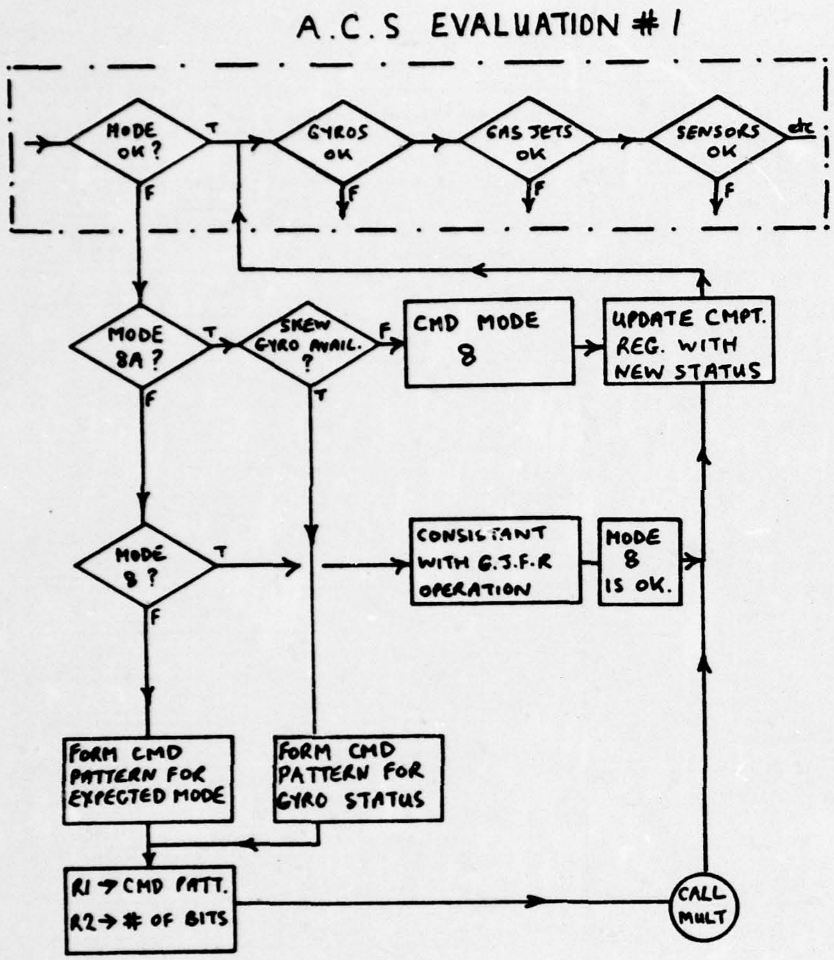
R99	DIRECT CMD φ	ACTUAL MIRROR POSTN/ NO. OF MIRROR POSTN. CMDS. REQ.
R100	PLANNED CMD φ	AT ANY INSTANT, SPECIFIES NO OF MULT. CMDS STILL TO BE SENT.
R101	DIRECT CMD φ	SPECIFIES ACTUAL BIT TO BE EXAMINED.
R102	DIRECT CMD φ	SPECIFIES ACTUAL SYLL. TO BE EXAMINED.
R103	SET UP φ	SPECIFIES TRACK NO. EXPECTED.
R104	DIRECT CMD φ	CONTAINS SYLL. IDENTIFIED IN R102.
R105	—‖—	CONTAINS BIT IDENTIFIED IN R101.
R106	RPLY. MULT CMDS	SPECIFIES CMD. PATTERN SENT TO ACS REG. 'A'.
R107	—‖—	AS R106, BUT FOR REG. 'B'.
R108	VDU DIAGNOSTICS	SPECIFIES O/P DEVICE. (LPR OR VDU).
R109	SET UP φ	CONTAINS REG. NO. TO BE CHANGED.
R110	—‖—	CONTAINS NEW LIMIT VALUE FOR UPDATE.
R111	—‖—	SPECIFIES O/P DEVICE
R112 — R114	—‖—	PARAMETER LIMITS
R115	CMD VERIFY φ	INTERNAL MANIPULATION.
R116	ACTUAL VERIFY φ	SPECIFIES IF CMD SENT WAS A PITCH RATE DEMAND.
R117	CMD VERIFY φ	INTERNAL MANIPULATION.
R118 — R200	SET UP φ	PARAMETER LIMITS.
R201	—‖—	USED TO CLEAR FLAGS (1→250) [NOTE: NOT FLAG #35]
R202	—‖—	CONTAINS PRECISE CONTENTS OF REG 'A'.
R203	—‖—	CONTAINS PRECISE CONTENTS OF REG 'B'.
R204	—‖—	CONTAINS NO. OF BITS FOR REG 'A'.
R205	—‖—	CONTAINS NO. OF BITS FOR REG. 'B'.

R206	SET UP φ	SPECIFIES BIT PATTERN FOR REG. 'A' (16 BITS).
R207	—‖—	AS R206, BUT FOR REG 'B'.
R208	—‖—	
R209 → R247	VDU # 1	MANIPULATION OF SYLLABLE CONTENTS.
R248 → R293	HEAT BALANCE DIAG.	MANIPULATION OF SYLLABLE CONTENTS.
R294		
R295		
R296		
R297		
R298		
R299		
R300		
R301		
R302		
R303	ACS ASSESS. φ2	DETERMINES STATUS OF SUN PRESENCE SIGNALS
R304	—‖—	AS R303
R305	CANOPUS EVAL φ	ACTUAL MIRROR AND THRESHOLD POSITIONS.
R306	2ND RPLY IN PASS	SPECIFIES T.R. TRACK IDENT.
R307	—‖—	AS R306
R308	ACS φ3	CONTAINS ACTUAL MODE STATUS
R309		
R310	SET UP φ	SPECIFIES MIN. NO. OF M.F. FOR STAR LOCK ASSESS. IN REPLAY.
R311		
R312	ACS φ2	INTERNAL MANIPULATION FOR NON INVERSION OF BIT 7 IN GAS JET STATUS.
R320	SET UP φ	SPECIFIES –VE GYRODRIFT RATE. (TO ACHIEVE ZERO PITCH RATE – STARLOCK)

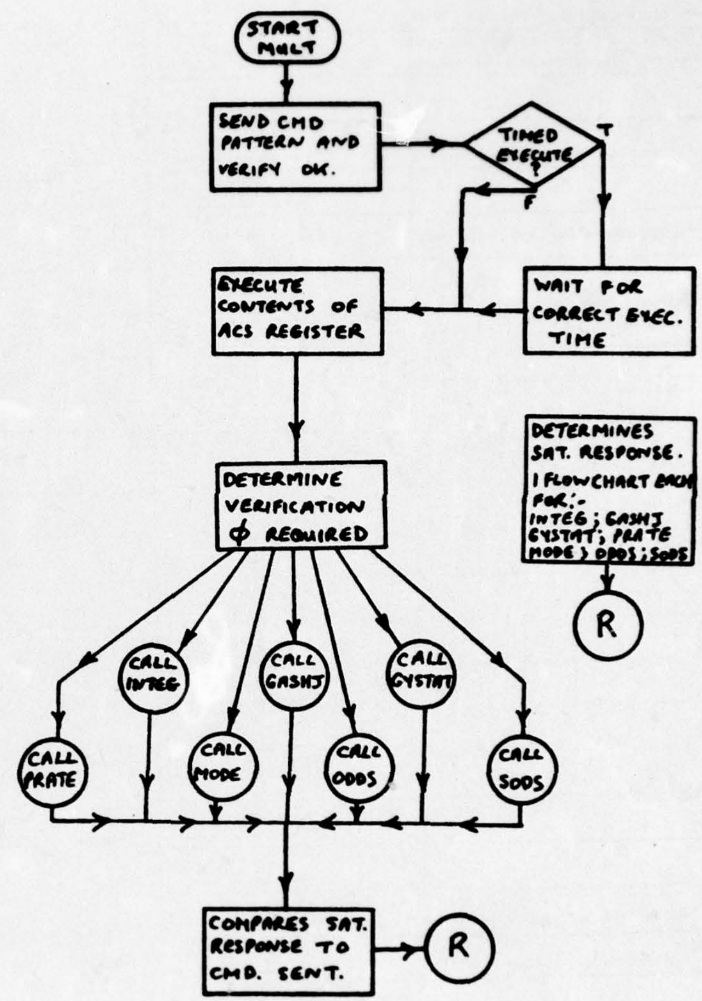
Fig.D91 Register Number 2

Fig.D91

Fig.D92



Remedial action block diagram



Multiple command system block diagram

Fig.D92 ACS ϕ No.1

DAY NO 259 PASS M7 X4 QUICK LOOK ANALYSIS DATE 1974 9 16

STATUS

	START OF PASS	END OF PASS
WORD 1	*000 (MODE 3)	*004 (MODE 5)
WORD 2	*100	*100
WORD 3	*210	*210
GJFR ENABLED	YES	YES
FINE S.S.	YES	YES
PRIM S.S.	YES	YES
T.R. A	YES	YES
T.R. B	NO	NO
TRACK NO.	4	4
STATUS DD30	*000	*000
TX	A	A
ADC	A	A
U SWITCH B	YES	YES
U SWITCH C	YES	YES
U SWITCH D	YES	YES
MIRROR POSITION	11	11
CANOPUS THRESHOLD	01	01
ALBEDO INT.	001	001

Fig.G1a

Fig.G1b

DAY NO 259 PASS M1 X4 QUICK LOOK ANALYSIS DATE 1975 9 16

POWER SUPPLIES

	MIN	MEAN	MAX
V RAB	17.87	18.14	18.18
IARRAY	1.108	2.222	2.363
V BATT	16.93	16.93	16.93
I BATT	.043	.043	.043
V +12	11.95	11.95	11.95
I +12	.395	.407	.426
V -12	-12.10	-12.10	-12.10
I -12	.288	.288	.288
V +5	4.997	4.997	4.997
I +5	.935	.975	1.014
V -5	-5.053	-5.053	-5.053
I -5	.091	.096	.104
V+12TR	11.92	11.92	11.92
I+12TR	.020	.021	.026
V-12TR	-12.09	-12.09	-12.09
I-12TR	.020	.020	.021
T BATT	17.67	17.67	17.67
T PRDU	11.64	12.17	12.42
T CONV	9.25	9.74	10.06

Fig.G1b

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DAY NO 259 PASS M1 X4 QUICK LOOK ANALYSIS DATE 1974 9 16

DATA HANDLING

	DD20 2 3	DD30 1 2 3 4 5 6 7 8	DD50 1 2 3	TRN
START OF PASS	1 0	0 0 0 0 0 0 0 0	1 1 0	4
END OF PASS	1 0	0 0 0 0 0 0 0 0	1 1 0	4

NUMBER OF FRAMES DIRECT	GOOD	836
	BAD	1
REPLAY	GOOD	442
	BAD	2

T.R. MOVEMENT RATIO (1 - 0) A .89

B .00

	MIN	MEAN	MAX
TX O/P	1.255	1.255	1.255
PRES A	590.6	590.6	590.6
PRES B	411.1	411.1	411.1
T REF	5.415	5.415	5.415
ADC +A	2.511	2.511	2.511
ADC -A	-4.673	-4.673	-4.673
ADC OV	-.001	-.001	-.001
ADC +B	2.511	2.511	2.511
ADC -B	-4.673	-4.673	-4.673
I+12TR	.020	.021	.026
I-12TR	.019	.019	.020
V +12	11.95	11.95	11.95
V -12	-12.10	-12.10	-12.10
V +5	4.997	4.997	4.997
V -5	-5.053	-5,053	-5,053
V+12TR	11.92	11.92	11.92
V-12TR	-12.09	-12.09	-12.09
AGC A	-119.6	-109.0	-66.9
AGC B	-108.2	-108.2	-68.6
TEMP A	9.246	9.246	9.246
TEMP B	31.92	31.92	31.92

Fig.G1c

Fig.G1d

DAY NO 259 PASS M1 X4 QUICK LOOK ANALYSIS DATE 1974 9 16

IR4 AND IR3 GAIN ASSESSMENT

GAIN ON 4 = 100 GAIN ON 3 = 93

TELEMETRY DIFF(4,3)	CHANNELS CH4	SIGNAL V4	VOLTS (93) V3	TYPE	MARGINS L	U	
-3.604	-1.101	3.329	5.362	1	2.20		
-3.604	-1.101	3.329	5.362	1	2.20		
-3.486	-1.101	3.329	5.304	1	2.09		
-3.722	-1.140	3.292	5.381	1	2.32		
-3.800	-1.218	3.219	5.341	1	2.40		
.675	.156	4.497	4.502	1	-2.08		
.675	1.255	5.520	5.601	2		1.28	
.754	1.216	5.483	5.523	2		1.35	
.715	1.216	5.483	5.542	2		1.31	
.715	1.216	5.483	5.542	2		1.31	
.675	1.216	5.483	5.562	2		1.28	**
.715	1.177	5.447	5.503	2		1.31	
.793	1.137	5.410	5.425	2		1.39	
.754	1.137	5.410	5.444	2		1.35	
.793	1.137	5.410	5.425	2		1.39	
.715	1.137	5.410	5.464	2		1.31	
.793	1.098	5.374	5.386	2		1.39	
4.366	1.098	5.374	3.619	3			
4.366	1.059	6.337	3.580	3			
4.366	1.098	5.374	3.619	3			
4.366	.902	5.191	3.423	3			
4.366	1.098	5.374	3.619	3			
2.717	1.177	5.447	4.513	2		3.32	
.597	1.255	5.520	5.640	2		1.20	
.675	1.255	5.520	5.601	2		1.28	
-3.054	.274	4.607	6.464	1	1.65		
-2.425	- .472	3.913	5.407	1	1.03		
-2.583	- .590	3.804	5.367	11	1.18		
-2.505	- .551	3.840	5.368	1	1.10		**
-2.583	- .551	3.840	5.407	1	1.18		
-2.937	- .669	3.731	5.464	1	1.54		
-3.447	- .944	3.475	5.441	1	2.05		
-3.918	-1.179	3.256	5.439	1	2.52		
-4.154	-1.297	3.146	5.437	11	2.75		
-3.800	-1.179	3.256	5.380	1	2.40		
-3.682	-1.061	3.365	5.440	1	2.28		
-3.643	-1.101	3.329	5.381	1	2.24		
-3.643	-1.101	3.329	5.381	1	2.24		
-3.643	-1.022	3.402	5.460	1	2.24		
-3.290	- .944	3.475	5.364	1	1.89		
-3.722	-1.179	3.256	5.342	1	2.32		

GAINS CH4	CH3	MARGINS L	U
100	93	1.08	1.27
93	86	.85	1.28

	CH4	CH3	MARGIN
GAIN SETTINGS WERE	100	93	1.10
BEST SETTINGS ARE	100	93	1.08

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Fig.G1d

DAY NO 259 PASS M1 X4 QUICK LOOK ANALYSIS DATE 1974 9 16

DIRECT DATA

MINOR FRAMES 1790 TO 2059

GOOD FRAMES 270

BAD FRAMES 0

REPLAY DATA

MINOR FRAMES 1345 TO 1788

GOOD FRAMES 442

BAD FRAMES 2

DIRECT DATA

MINOR FRAMES 2076 TO 2642

GOOD FRAMES 566

BAD FRAMES 1

Fig.G1e

Fig.G1f

DAY NO 259 PASS M1 X4 QUICK LOOK ANALYSIS DATE 1974 9 16

TEMPERATURES

	MIN	MEAN	MAX
STRUCTURE 1	77.0	77.8	78.0
2	73.0	73.9	74.0
3	40.4	41.4	42.0
4	4.1	6.3	8.4
5	-26.3	-24.2	-22.9
6	4.1	4.1	4.1
7	2.3	4.3	5.0
8	22.0	23.4	24.1
9	25.5	25.7	26.2
GYRO R	57.7	57.7	57.7
Y	58.5	58.5	58.5
P	59.3	59.3	59.3
S	59.3	59.3	59.3
FINE SUN	47.6	47.6	47.6
PRIM SUN	67.8	67.8	67.8
HORIZON DET	17.7	18.5	19.1
ELECTRONICS	29.0	29.0	29.0
TANK 1	17.0	17.0	17.0
2	17.0	17.0	17.0
3	16.3	16.3	16.3
4	17.8	17.8	17.8
5	16.3	16.3	16.3
6	14.9	15.4	15.6
7	14.2	14.2	14.2
8	12.9	13.3	13.6
9	17.0	17.0	17.0
10	12.3	12.7	12.9
GAS JET 1 P+	11.6	11.9	12.4
2 P-	10.1	10.6	10.9
3 Y+	4.1	4.1	4.1
4 Y-	5.0	5.1	5.9
5 R+	39.7	40.4	41.3
6 R-	-1.5	-.8	-.5
I.R. DET	6.9	7.8	7.2
I.R. LENS	6.7	6.8	7.0
CANOPUS	5.0	5.0	5.0
ALBEDO	5.0	5.7	5.9
SOLAR ARRAY 1	80.5	80.5	80.5
SOLAR ARRAY 2	93.2	93.2	93.2

Fig.G1f

TR 76016

STAR LOCK OPERATIONS SEQUENCE

PASS	SEQUENCE
E1	
E2	Mode 3 - zero rate commanded.
E3	
M1	From M1 data, computer program SLK determines attitude fix, extrapolates attitude at T1, calculates both the required attitude at T2 and the pitch integrator rate at T1 (x deg/H) to achieve that attitude.
M2 T1	x degs/H commanded.
M3	
E1 T2	Mode 5 commanded, +20 deg/H (vega)/- 20 deg/H (canopus) prime rate commanded and pitch integrator rate removed.
E2	Direct Data assessment. Checks that Star Lock Trigger and 20 deg/H rate removed. If "yes", schedules Replay assessment, if "no" selects Mode 3 ie go back to start of sequence (at previous E2). Note, selection of Mode 3 removes final drive rate of ±20 deg/H. Replay assessment. Checks Star Presence set for greater than 'N' minor frames and prints minor frame number when Star Lock Trigger is first set. If Presence is set for less than 'N' minor frames (N is pre-specified), Mode 3 is scheduled automatically in planned command phase, ie restart sequence. If satisfactory Mode 5 (5A) remains & Star Lock continues each pass.

Fig.G2

LOOK PROGRAMS FOR X4 TELEMETRY DATA ANALYSIS

1) QLK Quick look
2) RLK Routine Look
3) SLK Star Look or Lock
4) WLK A.C.S. Parameter Lists
5) ELK Emergency Look
6) XLK Extra Word Look

	QLK	RLK	SLK	WLK	ELK	XLK
LOAD MAG. TAPE AND FIND PASS	✓	✓	✓	✓	✓	✓
ORBITAL ELEMENTS		✓	✓			
OPERATIONAL DATA SHEET			✓	✓	✓	✓
LINE PRINTER OUTPUT	✓	✓	✓	✓	✓	✓

Fig.G3

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